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OFFICE OF
CHEMICAL SAFETY AND
POLLUTION PREVENTION

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MEMORANDUM

DATE: May 16, 2017

SUBJECT: Pendimethalin – Transmittal of the Preliminary Environmental Fate and Ecological Risk Assessment for Registration Review

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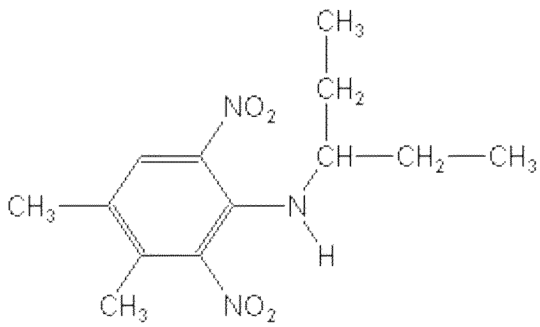
This memorandum transmits the preliminary ecological risk assessment for the registration review of the herbicide pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; CAS Registry Number: 40487-42-1; PC Code: 108501).

Office of Chemical Safety
and Pollution Prevention

Preliminary Environmental Fate and Ecological Risk Assessment for the Registration Review of Pendimethalin



N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine
CAS Registry Number: 40487-42-1
PC Code: 108501

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1. Executive Summary

Overview

The Environmental Fate and Effects Division (EFED) has completed the preliminary ecological risk assessment for the Registration Review of the herbicide pendimethalin (PC Code 108501; CAS Registry Number: 40487-42-1). The registered uses of pendimethalin are for agricultural crops (including vegetables, peanut, citrus, pome and nut trees, corn, cotton, and sugarcane) and non-agricultural crops (turf). Single maximum application rates range from 1.0 - 6.0 pounds of active ingredient per acre (lbs a.i./A) with up to a maximum of 3 treatments allowed, depending on the use site. Pendimethalin can be applied via foliar spray through either ground or aerial application methods or through chemigation.

Risk Conclusions Summary

As expected with an herbicide, there are LOC exceedances for terrestrial and aquatic plants. Using selected scenarios representing the breadth of pendimethalin application rates, aquatic vascular plants exceed the LOC for non-listed plants up to 3.5-fold and the listed species LOC up to 7.9-fold. Nonvascular aquatic plants exceed the LOC by 8.5-fold. While there are no currently listed aquatic nonvascular plant species, the RQs range as high as 63 for the highest use rate sites, (6.0 lbs ai/A/yr). Runoff RQs for the most sensitive plant species, ryegrass, at the highest application rate are 18 and 45 for sheet flow and channelized runoff respectively. Based on default AgDRIFT modeling, effects to the most sensitive monocot and dicot may extend greater than 1000 feet from the edge of the field.

For fish and aquatic invertebrates, risk quotients (RQs) are near to, but do not exceed the acute level of concern (LOC) of 0.5 for non-listed species with all use patterns. There are no exceedances of the acute risk LOC (0.5) for non-listed species, although the acute risk listed species LOC (0.05) is exceeded for all use patterns (RQs up to 0.32). The sugarcane use pattern, which has the highest application rates, also exceeds the chronic risk LOC (1.0) for fish (RQ=1.35). Additionally, benthic invertebrates appear to be potentially at risk from the sugarcane use pattern, with sediment-based RQs for *Chironomus dilutus* as high as 1.6 (LOC=1.0).

Risks to listed and non-listed birds (which serve as surrogates for reptiles and terrestrial-phase amphibians) are possible on both an acute and chronic basis. Acute risk LOCs (0.5) are exceeded for several forage/size class combinations with RQs as high as 1.6; in many cases where the acute risk LOC for non-listed species is not exceeded, the acute listed species LOC (0.1) is exceeded. Many forage classes exceed the chronic risk LOC (1.0), with RQs as high as 10-fold the LOC.

The acute risk LOC for non-listed mammals is exceeded only for small mammals foraging on short grass at the highest use rates, but multiple exceedances of the acute listed species LOC are noted. The chronic risk LOC is exceeded across use patterns with the highest RQ exceeding the LOC by 12-fold (RQ=12).

Acute oral and contact honey bee toxicity data indicate a low likelihood of adverse effects from exposure to pendimethalin for all use patterns. However, chronic oral toxicity data for young adult bees and acute and chronic larval honey bee data are not available. Therefore, the potential for effects to individual adult honey bees or their brood (eggs, larvae, and pupae) is uncertain.

Environmental Fate Summary

Pendimethalin dissipates in the environment by sorption to soil, microbial degradation, and by volatilization into air. Microbes can degrade pendimethalin to CO_2 and many degradates. Also, the volatilization can be significant because pendimethalin has limited water solubility (0.3 mg/L), relatively high vapor pressure, and a high log K_{ow}. Persistence in the terrestrial environment will decrease with increasing temperature, moisture, or decreasing soil organic carbon because the extent of sorption of pendimethalin is related to soil organic content. Pendimethalin residues in field studies are tightly bound to soil and sediment particles, which is consistent with the laboratory mobility studies (mean K_{oc} 17040). Pendimethalin degraded in soil under aerobic soil conditions with a half-life range of 95-1322 days. Terrestrial field dissipation data that are consistent with laboratory data have also been provided. In an Indiana field dissipation study, the half-lives ranged from 84-147 days. However, in field dissipation studies in Louisiana (LA) and Mississippi (MS), the half-lives ranged from 4 to 82 days, with most studies containing half-lives of <20 days.

Ecological Effects Summary

Pendimethalin is highly to very highly toxic to freshwater and estuarine/marine fish and invertebrates on an acute exposure basis. Chronic toxicity studies on freshwater fish and invertebrates showed effects on growth and reproduction following exposure. Data for vascular and non-vascular aquatic plants indicate that there are significant effects (on growth) following exposure to pendimethalin.

Pendimethalin is characterized as slightly toxic to practically non-toxic to birds on an acute oral and subacute dietary basis. Effects on 14-d survivor body weights were observed in chronic avian reproduction studies. For mammals, pendimethalin is slightly toxic on an acute oral basis and chronic effects (decreased pups born and decreased pup body weights) were observed. Seedling emergence and vegetative vigor studies with pendimethalin showed effects >25% for most species tested.

Pendimethalin is practically non-toxic to adult honey bees on an acute contact and acute oral basis.

Uncertainties and Identification of Data Needs

The environmental fate and ecological effects databases are considered complete for this risk assessment with the exception of data on pollinators. However, the remaining suite of Tier 1 honey bee studies are expected to be called in under an upcoming data call-in (DCI).

These required Tier 1 studies include:

- Non-guideline, OECD 237 (Tier I): Honey bee larval acute oral toxicity (TGAI)
- Non-guideline (Tier I): Honey bee adult chronic oral toxicity (TGAI)
- Non-guideline (Tier I): Honey bee larval chronic (repeat-dose) oral toxicity (TGAI)

RISK SUMMARY TABLE

Table 1. Summary of Risk Concerns to Taxonomic Groups from Current Uses of Pendimethalin[1]

Taxa	Exposure Duration	RQ Range[2]	Non-listed	Listed (Direct effect)	Additional Information
Fish	Acute	0.05 – 0.32	No	*Yes*	Chronic exceedances only at the highest use rates
	Chronic	0.12 – 1.35	*Yes*		
Aquatic invertebrates	Acute	0.02 – 0.16	No	*Yes*	
	Chronic	0.09 – 0.78	No		
Benthic invertebrates	Chronic	Not calculated	*No*		Despite statistcally significant findings, no biologically relevant effects were observed.
Mammals	Acute	<0.01 – 0.59	No	*Yes*	The number of forage item/size class exceedances are reduced at lower use rate scenarios
	Chronic	0.03 – 12.01	**Yes**		
Birds	Acute	<0.01 – 1.6	*Yes*	*Yes*	The number of forage item/size class exceedances are reduced at lower use rate scenarios
	Chronic	0.11 – 10.21	**Yes**		
Terrestrial invertebrates	Acute Adult		*No*		Tier 1 larval and adult oral acute and chronic data are not available
	Chronic Adult	No data			
	Acute Larval	No data			
	Chronic Larval	No data			
Aquatic plants	N/A	1.2 – 63.3 (listed) 0.6 – 8.5 (non-listed)	**Yes**	**Yes**	
Terrestrial plants	N/A	0.95 – 90 (listed) 0.67 – 45 (non-listed)	**Yes**	**Yes**	

EEC=estimated environmental concentration; LOC=level of concern; N/A=not applicable; NOAEC=no observable adverse effect concentration; RQ=risk quotient

1 'Risk Concern' cells are shaded based on maximum RQ values as follows:

- "**Yes**" indicates high certainty in a high likelihood of direct adverse effects (*e.g.*, multiple lines of evidence, RQs exceed LOCs, RQs based on reliable data and exposure estimate);
- "*Yes*" or "*No*" indicates lower certainty (*e.g.*, low confidence in data used to calculate RQs, lack of data, or few lines of evidence support the conclusion); and
- "No" indicates a high certainty in a low likelihood of direct adverse effects (*e.g.*, full data set, high confidence in exposure estimates and toxicity dataset).

2 Chronic risk LOC = 1.0; Acute risk LOC for non-listed species = 0.5; Acute risk LOC for listed terrestrial animals= 0.1; Acute risk LOC for listed aquatic animals = 0.05; Aquatic and terrestrial plant risk LOC = 1.0.

2.0 Problem Formulation

2.1. Nature of Regulatory Action

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), all pesticides distributed or sold in the United States must be registered by the United States Environmental Protection Agency (EPA). To determine whether a pesticide can be registered, the EPA evaluates its safety to non-target species based on a wide range of environmental and health effects studies. In 1996, FIFRA was amended by the Food Quality Protection Act (FQPA), and EPA was mandated to implement a new program for the periodic review of pesticides, *i.e.*, Registration Review[1]. The Registration Review program is intended to ensure that as the ability to assess risk evolves and as policies and practices change, all registered pesticides continue to meet the statutory standard of no unreasonable adverse effects to human health and the environment. Changes in science, public policy, and pesticide use practices will occur over time. Through the Registration Review program, the Agency periodically reevaluates pesticides to make sure that as changes occur, products in the marketplace can be used safely.

2.2. Stressor Source and Distribution

2.2.1. Nature of the Stressor

Pendimethalin is a non-selective broad spectrum herbicide used for control of annual and perennial broadleaf and grass weeds in agricultural and non-agricultural lands. Pendimethalin is a cell growth inhibitor that prevents seedling development and is herbicidally active on the roots and coleoptiles of susceptible weeds. Pendimethalin was patented by American Cyanamid in 1972 and first registered in the United States in 1974. Pendimethalin is a dinitroaniline herbicide which controls certain broadleaf weeds and grassy weed species in certain crop and non-crop areas. It is applied to soil pre-plant, pre-emergence, and post-emergence, with ground and aerial equipment.

The Reregistration Eligibility Decision Document (RED), published in June 1997, concluded that uses of pendimethalin would not cause unreasonable risks to the environment, though risks were identified for listed and non-listed fish and aquatic invertebrates as well as terrestrial and aquatic plants and listed and non-listed birds and mammals.

Pendimethalin is currently registered for use on a variety of agricultural crops, turf, and ornamentals. It can be broadcasted by air or ground and/or be banded as a directed spray or applied via irrigation equipment. Currently registered maximum single application rates of pendimethalin range from approximately 1 to 6 lb a.i./A, and maximum seasonal application rates range from 1.24 to 6 lb a.i./A. Recent pendimethalin ecological risk assessments include the litigation-related California red-legged frog (CRLF) assessment (USEPA, 2009), a Section 3 new use assessment for artichoke, asparagus, brassica subgroup 5a, and grapes (USEPA, 2007; DP 334069), and a Section 3 new use assessment for edamame and cold- and warm-weather forage grass (USEPA, 2010; DP 378514).

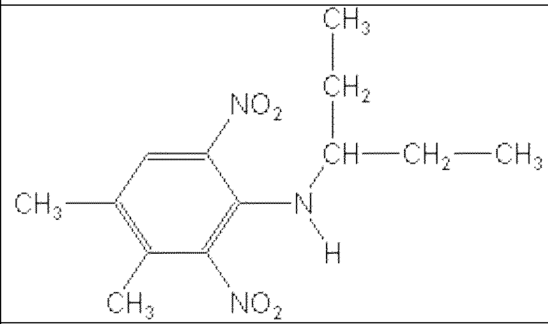
[1] http://www.epa.gov/oppsrrd1/registration_review/

The most recent review performed for pendimethalin were the Section 3 New Use registrations for use on Caneberry Subgroup 13-07A, Bushberry Subgroup 13-07B, Crop Group Conversion for Tree Nut Group 14-12; and Cool and Warm Season Forage Grasses (USEPA, 2015; DP 420007, 421110, 421124), and for use on hops and multiple crop group/subgroup conversions including Low Growing Berry Subgroup 13-07G, Onion Subgroups 3-07 A & B, Sunflower Subgroup 20B, Citrus Fruit Group10-10, Pome Fruit Group 11-10, Stone Fruit Group 12-12, and Fruiting Vegetable Group 8-10 (USEPA, 2015; DP 416208, 416209, 416286).

The screening-level risk assessment indicated that labeled uses of pendimethalin on these crops had the potential to cause direct acute effects to listed freshwater fish, estuarine/marine fish, estuarine/marine invertebrates, and aquatic vascular and non-vascular plants (including risk to non-listed aquatic non-vascular plants). With respect to terrestrial animals, direct acute and chronic effects to listed and non-listed birds and mammals are possible. In addition, acute and chronic effects to piscivorous birds and mammals via ingestion of pendimethalin residues in aquatic biota may be possible; however, depuration of pendimethalin was observed in the submitted bluegill sunfish study, which may reduce the potential for bioaccumulation. Risks to terrestrial plants are also predicted.

The general chemical profile of pendimethalin is shown in Table 2.

Table 2. Chemical Profile of Pendimethalin.

Common name	Pendimethalin
Chemical name Chemical formula	N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine C13H19N3O4
Structure	
SMILES Notation	[O-][N+](=O)c1c(c(cc([N+]([O-])=O)c1NC(CC)CC)C)C
Pesticide type	Herbicide
Chemical class	Dinitroaniline
CAS number	40487-42-1
PC code	108501
Molecular Weight	281.31 g/mol
Octanol-water partition coefficient (Log K_{OW}) pH 7, 20 °C	5.18

2.3. Receptors

2.3.1. Aquatic and Terrestrial Effects

The receptor is the biological entity that is exposed to the stressor (USEPA, 1998). Consistent with the process described in the Overview Document (USEPA, 2004a), this risk assessment uses a surrogate species approach. Toxicity data generated from surrogate test species, which are intended to be representative of broad taxonomic groups, are used to extrapolate potential effects on a variety of species (receptors) included under these taxonomic groupings.

Acute and chronic toxicity data from studies submitted by pesticide registrants along with the available open literature are used to evaluate potential direct effects to aquatic and terrestrial receptors. The open literature studies are located through EPA's ECOTOXicity database (ECOTOX; http://cfpub.epa.gov/ecotox/), which provides a source for locating single chemical toxicity data for aquatic life, terrestrial plants, and wildlife.

2.3.2. Ecosystems Potentially at Risk

The ecosystems potentially at risk are often extensive in scope; therefore, it may not be possible to identify specific ecosystems during the development of a nation-wide ecological risk assessment. However, in general terms, terrestrial ecosystems potentially at risk could include the treated field or tree(s) and immediately adjacent areas that may receive spray drift or runoff. Areas adjacent to the treated field or tree(s) could include cultivated fields, fencerows and hedgerows, meadows, fallow fields or grasslands, woodlands, riparian habitats, and other uncultivated areas.

Aquatic ecosystems potentially at risk include water bodies adjacent to or downstream from use sites, and might include natural or impounded lentic water bodies such as ponds, lakes and reservoirs, or flowing waterways such as streams or rivers including all adjacent off-channel habitats that are permanently or intermittently connected to flowing waters. For uses in coastal areas, aquatic habitat also includes marine ecosystems, including estuaries, embayments, and near-shore environments such as tidal marshes.

2.4. Assessment Endpoints

Assessment endpoints represent the actual environmental value that is to be protected, defined by an ecological entity (species, community, or other entity) and its attribute or characteristics (USEPA, 1998). For pendimethalin, ecological entities of potential concern include the following: birds, terrestrial- and aquatic-phase amphibians, reptiles, mammals, freshwater fish and invertebrates, estuarine/marine fish and invertebrates, non-target terrestrial plants, terrestrial invertebrates, and aquatic vascular and non-vascular plants. The attributes for each of these entities include growth, survival, and reproduction.

The assessment endpoints are intended to reflect population sustainability and community structure within ecosystems and hence relate back to ecosystems at risk. If risks are expected for given species/taxa based on the screening-level assessment, then risks might be expected to translate to higher levels of biological organization.

2.5. Conceptual Model

For a pesticide to pose an ecological risk, it must reach ecological receptors in biologically significant concentrations. An exposure pathway is the means by which a pesticide moves in the environment from a source to an ecological receptor. For an ecological pathway to be complete, it must have a source, a release mechanism, an environmental transport medium, a point of exposure for ecological receptors, and a feasible route of exposure. The conceptual model is intended to provide a written description and visual representation of the predicted relationships between pendimethalin, potential routes of exposure, and the predicted effects for the assessment endpoint. The conceptual model consists of two major components: the risk hypotheses and a conceptual model (USEPA, 1998).

The conceptual model used to depict the potential ecological risk associated with the existing uses of pendimethalin relies on previous assessments and the Agency's current understanding of the environmental fate and ecological effects of the chemical. Consistent with the intended use of pendimethalin as an herbicide, risk to non-target terrestrial and aquatic plants is expected. Effects on plants, which represent the primary producers in an ecosystem, may result in secondary effects on consumers which may include a broad range of taxa.

2.5.1. Risk Hypotheses

For pendimethalin, the following generic ecological risk hypotheses are being employed for this risk assessment:

Given the currently labeled uses of pendimethalin and its environmental fate properties, there is a likelihood of exposure to non-target terrestrial and aquatic organisms. When used in accordance with the label, pendimethalin may result in potential adverse effects upon the survival, growth, and reproduction of non-target terrestrial and aquatic organisms.

2.5.2. Conceptual Pathways Table

The environmental fate properties of pendimethalin indicate that for foliar applications, spray drift and runoff (including of eroded sediment) are potential transport mechanisms to aquatic habitats where non-target organisms may be exposed. It is expected that non-target terrestrial organisms can be exposed via spray drift of pendimethalin, and through consumption of exposed plants and invertebrates on treated fields. A summary of the transport pathways and the models used for those pathways in the assessment are shown in **Table 3**.

Pendimethalin may contaminate surface water from spray drift associated with aerial and ground spray application, or in runoff from rainfall events and through irrigation waters (chemigation). However, its high affinity to bind to soil and sediment particles should limit concentrations of pendimethalin in surface waters.

Pendimethalin dissipates in the environment by sorption to soil, microbial degradation, and by volatilization into air. Microbes can degrade pendimethalin to many minor (<10 % of applied radioactivity) degradates. Also, the volatilization can be significant because pendimethalin has very limited water solubility, moderate vapor pressure, and a high log K_{ow}. Persistence in the terrestrial environment will decrease with increasing temperature, moisture, or decreasing soil organic carbon because the extent of sorption of pendimethalin is related to soil organic content. Pendimethalin residues in field studies are tightly bound to soil and sediment particles, which is consistent with the laboratory mobility studies. See Table 9.

Two screening tools were utilized to assess the potential for exposure of pendimethalin to terrestrial organisms via inhalation and drinking water exposure. The Screening Tool for Inhalation Risk (STIR v.1.0, November 19, 2010) was used to calculate an upper bound estimate of exposure using vapor pressure and molecular weight of pendimethalin for vapor phase exposure, as well as the maximum application rate and method of application for spray drift. STIR incorporates results from several toxicity studies including acute oral and inhalation rat toxicity (oral LD_{50} = 1050 mg/kg-bw and inhalation LC_{50} >320 mg/L, respectively) as well as the most sensitive acute oral avian toxicity endpoint (mallard duck, LD_{50} = 1421 mg ai/kg bw).

Inhalation exposure via spray drift and vapor-phase of pendimethalin alone does not appear to be of concern. The analysis of the inhalation route in STIR does not consider that aggregation with other exposure pathways such as dietary, dermal, or drinking water may contribute to a total exposure that has a potential for effects to non-target animals. However, the Agency does consider the relative importance of other routes of exposure in situations where data indicate that pesticide exposures through other routes may be potentially significant contributors to wildlife risk (US EPA, 2004).

The Screening Imbibition Program (SIP v.1.0, Released June 15, 2010) was used to calculate an upper bound estimate of exposure from drinking water using pendimethalin solubility (0.3 mg/L), the most sensitive acute and chronic avian oral toxicity endpoint (mallard duck, LD_{50} = 1421 mg ai/kg bw and NOAEL = 141 mg/kg-diet, respectively) and the most sensitive acute and chronic mammalian toxicity endpoints (oral LD_{50} = 1050 mg/kg-bw and NOAEL = 500 mg/kg-bw, respectively). Drinking water exposure alone was determined not to be a potential pathway of concern for avian and mammalian species on an acute or chronic basis.

Although drinking water exposure alone does not appear to be of concern, this does not take into account that when aggregated with other exposure pathways (dietary food sources, dermal, inhalation) drinking water may contribute to a total exposure that has a potential for effects on non-target animals and should be explored further. Because there is a high degree of conservatism in the SIP 1.0 exposure estimate, there is limited expectation that use scenarios not triggering a SIP 1.0 concern would contribute significantly to aggregate risks from water plus diet when a refined water exposure model is incorporated in the actual quantitative risk assessment.

Although not available at this time, the Agency is actively pursuing modeling techniques to account for dermal exposure via direct application of spray and by incidental contact with contaminated vegetation, soil and water.

Table 3. List of the Various Models and the Related Taxa for which the Models will be Used to Assess Risk.

Environment	Taxa of Concern	Exposure Media	Exposure Pathway	Model(s) or Pathway	Attribute Change
Aquatic	Vertebrates/ Invertebrates (including sediment dwelling)	Surface water and sediment	Runoff and spray drift to water and sediment	PWC	Individual Organisms Food Chain Habitat Integrity
	Aquatic Plants (vascular and nonvascular)				Food Chain Habitat Integrity
	Riparian plants	See terrestrial exposure pathways			Habitat Integrity
Terrestrial	Vertebrate	Dietary items	Ingestion of residues in/on dietary items as a result of direct application	T-REX	Individual Organisms Food Chain Habitat Integrity
		Consumption of aquatic organisms	Residues taken up by aquatic organisms	KABAM	Individual Organisms Food Chain Habitat Integrity
	Plants	Spray drift/runoff	Runoff and spray drift to plants	TERRPLANT	Food Chain Habitat Integrity
		Surface water	*Residues in irrigation water*	*Not a major transport pathway*	
		Groundwater			
	Bees and other terrestrial invertebrates[1]	Contact Dietary items	Spray contact and ingestion of residues in/on dietary items as a result of direct application	See honey bee risk assessment guidance (USEPA *et al.*, 2014)	Individual Organisms Colony/Population Integrity
All Environments	All	Movement through air to aquatic and terrestrial media	Spray drift	AgDRIFT (Spray drift)	Individual Organisms Food Chain Habitat Integrity
			Atmospheric transport[2]	*Not a major transport pathway*	

Text in *italics* represent transport pathways that are not of concern.
[1] See pollinator SAP white paper for full list of modelling approaches for evaluating exposure used in this assessment (USEPA, 2012b).
[2] Pendimethalin is semi-volatile.

2.6. Analysis Plan

2.6.1. Residues of Concern

Available structures of observed degradates are provided in Appendix B (Tables B-1, B-2). The alcohol metabolites 3, 4, 5, and 7 are isomers and the acid metabolites 2 and 6 are isomers. Thus there are 3 groups of degradates; alcohols, acids and 2,6-dinitro-3,4-dimethylaniline (metabolite

1). These degradates are considered minor and do not form under aerobic conditions. Based on this, the parent alone is thought to be the residue of concern.

2.6.2. Measures of Exposure

Using EFED's standard suite of models, surface water estimated environmental concentrations (EECs) were generated for pendimethalin for the registered uses. The Pesticide in Water Calculator (PWC v 1.5+, February 2, 2016) estimates pesticide concentrations in surface water and groundwater bodies that result from pesticide applications to land. The calculator was designed as a regulatory tool for users in the USEPA's Office of Pesticide Programs and in the Pest Management Regulatory Agency of Health Canada. The calculator uses the Pesticide Root Zone Model (PRZM) (version 5.0+) and the Variable Volume Water Model (VVWM). EECs for pendimethalin were based on a total residue approach. Additional details on the model can be found at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#PWC. The spray drift model AgDrift is Tier 2 aquatic and terrestrial exposure from spray drift calculates deposition of pesticide due to spray drift.

Terrestrial wildlife are potentially exposed to pendimethalin via consumption of residues on food items from spray applications on various use sites. For spray applications, the T-REX model (Terrestrial Residue EXposure model; v. 1.5.2; June 6, 2013) is used to predict dietary exposure to pendimethalin residues on foliar surfaces and insects using the Kenaga nomogram as modified by Fletcher (Fletcher *et al.*, 1994; Hoerger and Kenaga, 1972). In this assessment, the default foliar dissipation half-life of 35 days was used for terrestrial modeling purposes. Additionally, the influence of lower foliar dissipation half-live values on risk was explored. Estimated exposures of terrestrial insects to pendimethalin are evaluated. Additional details on the model may be found at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#terrestrial.

The TERRPLANT (v. 1.2.2; October 29, 2009) model is used to derive EECs relevant to terrestrial and wetland plants for the registered uses of pendimethalin. The model assumes that default fractions of the intended application will be transported to an adjacent field through runoff and spray drift. Measures of exposure to terrestrial plants are expressed as a fraction of the mass of the pendimethalin applied to a treated field. Additional details on the model may be found at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/terrplant-version-122-users-guide-pesticide-exposure.

2.6.3. Measures of Effect

Measures of effect are obtained from a suite of registrant-submitted guideline studies that were conducted with a limited number of surrogate test species (**Table 4**). The test species are not intended to be representative of the most sensitive species but rather were selected based on their ability to thrive under laboratory conditions. Toxicity testing reported in this risk assessment utilizes surrogate species to represent all freshwater fish (2000+) and bird (680+) species in the U.S. In addition, the ECOTOX database was searched in November 2016 to provide more ecological effects data for pendimethalin. No data were further examined since no endpoints were more sensitive (lower) than endpoints available from submitted studies or were available for amphibians, freshwater molluscs, or reptiles.

The acute measures of effect used in this screening-level assessment are the LD_{50} (Lethal Dose), LC_{50} (Lethal Concentration), EC_{50} (Effects Concentration), and IC_{50} (Inhibition Concentration). These are measures of acute toxicity which result in 50% of the respective effect in tested organisms. The endpoints for chronic measures of exposure are the NOAEC (No Observed Adverse Effects Concentration) and the NOAEL (No Observed Adverse Effects Level). Toxicity studies were submitted for freshwater fish and invertebrates, estuarine/marine fish and invertebrates, aquatic and terrestrial plants, birds, mammals, and honey bees. The endpoints used for risk characterization were derived from studies which underwent review and were classified as "acceptable" (conducted under guideline conditions and considered to be scientifically valid) or "supplemental" (conditions deviated from guidelines but the results are considered to be scientifically valid).

Table lists the measures of environmental exposure and ecological effects used to assess the potential risks of Pendimethalin to non-target organisms. The methods used to assess the risk are consistent with those outlined in the document "*Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs*" (USEPA, 2004a).

Table 4. Measures of Exposure and Effect Used in Assessing Potential Risks Associated with the Proposed Uses of Pendimethalin.

Assessment Endpoint		Measures of Ecological Effect[1]	Measures of Exposure
Birds[2]	Survival	Lowest acute LD_{50} (single oral dose test) and LC_{50} (subacute dietary test)	Upper-bound residues on food items
	Reproduction and Growth	Lowest NOAEC (21-week reproduction test)	
Mammals	Survival	Lowest acute LD_{50} (single oral dose test) and LC_{50} (subacute dietary test)	
	Reproduction and Growth	Lowest NOAEC (2-generation reproduction test)	
Aquatic Animals (Fish and invertebrates)[3]	Survival	Lowest tested LC_{50} or EC_{50} (acute toxicity test)	Peak EECs[4]
	Reproduction and Growth	Lowest NOAEC (early life-stage, full life-cycle tests, 10-day sediment tests, or chronic sediment tests)	21-day EECs for invertebrates and 60-day EECs for fish[4]
Terrestrial plants[5]	Survival and growth	Lowest EC_{25} (for non-listed plants) and corresponding NOAEC (for listed plants) (endpoints derived for monocots and dicots from seedling emergence and vegetative vigor studies)	Estimates of runoff and spray drift to non-target areas
Insects[6]	Survival	Lowest honey bee LD_{50} (acute contact and acute oral test)	Upper-bound residues on tall grass[7]

Aquatic plants (vascular and non-vascular)	Survival and growth	Lowest EC_{50} (for non-listed plants) and corresponding NOAEC or EC_{05} (for listed plants)	Peak EECs[4]

[1] The most sensitive species tested within taxonomic groups is used for screening-level risk assessments.
[2] Birds represent surrogates for terrestrial-phase amphibians and reptiles.
[3] Freshwater fish represent surrogates for aquatic-phase amphibians.
[4] Aquatic EECs are based on modeling described in **Section 3.2.2.1**.
[5] Four species of two families of monocots , six species of at least four dicot families.
[6] Risk to terrestrial invertebrates from pendimethalin use is quantitatively evaluated against the acute non-listed terrestrial invertebrate LOC of 0.4.

[7] The tall grass residue value from the T - REX model (v. 1.5.2) is used as a surrogate for pesticide concentrations in nectar and pollen (USEPA, 2014).

2.6.4. Integration of Exposure and Effects

The exposure and toxicity effects data are integrated in order to evaluate the risks of adverse ecological effects on non-target species. For the risk assessment of pendimethalin, the risk quotient (RQ) method is used to compare estimated exposure and measured toxicity values. The RQ method involves dividing estimated environmental concentrations (EEC) by acute and chronic toxicity values. The resulting RQs are then compared to the Agency's Levels of Concern (LOC) (USEPA, 2004a) (**Table**). The LOCs are used to indicate when applications of pendimethalin, as directed on the label, have the potential to cause adverse effects to non-target organisms from exposure to Pendimethalin.

Table 5. Agency Risk Quotient (RQ) Metrics and Levels of Concern (LOC) Per Risk Class.

Risk Class	Risk Description	RQ	LOC
Aquatic Animals (fish and invertebrates)			
Acute	Potential for effects to non-listed animals from acute exposures	Peak EEC/LC_{50}[1]	0.5
Acute Listed Species	Listed species may be potentially affected by acute exposures	Peak EEC/LC_{50}[1]	0.05
Chronic	Potential for effects to non-listed and listed animals from chronic exposures	60-day EEC/NOAEC (fish)	1
		21-day EEC/NOAEC (invertebrates)	
Aquatic Plants			
Non-Listed	Potential for effects to non-listed plants from exposures	Peak EEC/IC_{50}	1
Listed	Potential for effects to listed plants from exposures	Peak EEC/NOAEC	1
Terrestrial Animals (mammals and birds)[2]			
Acute	Potential for effects to non-listed animals from acute exposures	EEC/LC_{50} (Dietary)	0.5
		EEC/LD_{50} (Dose)	
Acute Listed Species	Listed species may be potentially affected by acute exposures	EEC/LC_{50} (Dietary)	0.1
		EEC/LD_{50} (Dose)	

Chronic	Potential for effects to non-listed and listed animals from chronic exposures	EEC/NOAEC	1
Honey bees			
Acute	Potential for effects to individual bees or brood due to contact and dietary exposure.	Contact EEC/acute contact LD_{50} Diet EEC/ acute oral LD_{50} Diet EEC/ Larval LD_{50}	0.4
Chronic	Potential for effects to individual bees or brood due to contact and dietary exposure.	Diet EEC/ adult NOAEL Diet EEC/ larval NOAEL	1.0
Terrestrial and Semi-Aquatic Plants			
Non-Listed	Potential for effects to non-target, non-listed plants from exposures	EEC/ IC_{25}	1
Listed Plant	Potential for effects to non-target, listed plants from exposures	EEC/ NOAEC EEC/ IC_{05}	1

[1] LC_{50} or EC_{50}.
[2] EEC based on upper bound Kenaga nomogram values for foliar exposure.

3. Analysis

3.1. Use Characterization

Use patterns

Pendimethalin was patented by American Cyanamid in 1972 and first registered in the United States in 1974. Pendimethalin is a dinitroaniline herbicide which selectively controls certain broadleaf weeds and grassy weed species in certain crop and non-crop areas. It is applied to soil pre-plant, pre-emergence, and post-emergence, with ground and aerial equipment.

Pendimethalin is currently registered for use on a variety of agricultural crops, turf, and ornamentals (Table 6; based on the BEAD LUIS report, 6/30/2016).

Pendimethalin is formulated as a granule (G), micro-encapsulation (M), and emulsifiable concentrates (EC). This assessment evaluates risk based on currently labeled maximum application rates. Maximum single application rates for pendimethalin, numbers of applications per year, application intervals and application methods for all registered uses are provided in Table 6.

Due to the large number of registered uses for pendimethalin, crops were grouped according to generic crop grouping such as pome fruits, stone fruits, etc. In addition, within each group of crops due to the differences in application rates, only the representative scenario application rates were modeled to bracket the range of potential exposures.

Table 6. Pendimethalin Application Rates for the Various Uses.

Use	Max. Single App. Rate (lbs a.i./A)	Max Annual Rate (lb a.i./A)	Max No. App. (Interval -days)	Application Method
Perennial warm-season forage grasses. Bermudagrass. Perennial cool-season forage grasses. Alfalfa grown for forage/hay. Alfalfa grown for seed.	4 4	4 [1] 4	1 1	Broadcast, Impregnated material application Broadcast, Impregnated material application
Artichoke [A] Asparagus (60 d pre harvest)	3.895	3.895	1	Broadcast Broadcast, Banded.
African marigold	2	4	2 (30)	Broadcast, Impregnated material application
Fruiting Vegetables (tomato), Fruiting Vegetables (all others) [A] (pre planting) Green Onions [A]	1.5 1	1.5 2	1 2 (30)	Broadcast Broadcast
Mint (pepper, spear) [A]	2	2	1	Broadcast, Impregnated material application
Potato Edamame (vegetable soybean) Grain Sorghum Peanut Forage Legumes	1.5 1.5 1.5 1.5 1.24	1.5 1.5 1.5 1.5 1.24	1 1 1 1 1	Broadcast, Impregnated material application
Leaf Lettuce Leafy Brassica Greens Brassica Head and Stem Vegetables (Broccoli)	1 1	1 1	1 1	Broadcast Broadcast
Citrus Fruit Trees (bearing and nonbearing)	6	6	3	Broadcast, Banded
Dry Bulbs (garlic, onions, shallots) Lentils [A] (fall or spring)	1.5 1.5	1.5 1.5	1 1	Broadcast
Strawberry Strawberry (and other low-growing berries [A] (pre transplanting)	1.65	2.85	2 (NA)	Broadcast
Carrot [A] (pre crop emergence) Carrot grown for seed production	2	2	1	Broadcast
Date palm tree, Fig (nonbearing only), Olive trees (bearing and nonbearing), Pomegranate trees (bearing and nonbearing), Tree Nuts (bearing and nonbearing) [G]	6	6	3	Broadcast, Banded
Pome Fruit Trees (bearing and nonbearing), Stone Fruit Trees (bearing and nonbearing), [G]	4	4	2 (30)	Broadcast, Banded
Grape (bearing and nonbearing) Small Fruit Climbing Vines (bearing and	6	6	2 (30)	Broadcast, Banded

nonbearing) [G] (any time after fall harvest)				
Corn (field, pop, seed, sweet) Sunflower	2 1.73	2 1.73	1 1	Broadcast, Impregnated material application
Bushberries (bearing and nonbearing) Caneberries (bearing and nonbearing) Juneberry Tree (bearing and nonbearing)	6 6 4	6 6 4	1 1 2 (30)	Broadcast, Banded
Cotton	2	2	1	Broadcast, Impregnated material application
Sugarcane Ornamentals	4	6	2 (NA)	Broadcast
Hops	4	4	1	Broadcast, Banded
Tobacco	1.73	1.73	1	Broadcast, Impregnated material application

NA: Not available.
[1] One label, EPA Reg. No. 9198-191, was discovered to allow a maximum annual application rate up to 9.0 lbs a.i./A for use on warm season turf grasses. This rate is considerably higher than the maximum annual application rate allowed for similar uses. If this rate is intentional and not an error on the label for EPA Reg. No. 9198-191, it will be modeled following the public comment period in an addendum.

3.2. Exposure Characterization

3.2.1. Environmental Fate and Transport Characterization

The general physical/chemical properties of pendimethalin are summarized in **Table 7**. Environmental fate and transport-related properties of pendimethalin are characterized in further detail in the following sections.

Table 7. Environmental Fate Data Summary for Pendimethalin.

Parameter	Value	Reference
Vapor Pressure (Torr)	9.4×10^{-6}	TRID 470246023
Solubility in Water at 25°C (mg/L)	0.30	TRID 470246023
Octanol-water partition coefficient (Log K_{OW}) pH 7, 20 °C	5.18	Foot Print Pesticide Database @http://sitem.herts.ac.uk /aeru/footprint/en/index.htm
Mobility		
Freundlich soil partitioning coefficient (L/kg_{oc})	17,040 mL/g O.C. (U.S. soils) (avg of 5 values, 13000 – 29400)	MRID 00153765, and 43041901
Persistence in Soil/Water (days)		

Hydrolysis half-life (25°C)	Stable (pH 5, 7, 9)	MRID 00106777
Aqueous photolysis half-life (25°C)	21	MRID 00153763, and 43808201
Aerobic aquatic metabolism half-life (20°C)	24.1, 41.4	MRID 47385201
Anaerobic aquatic metabolism half-life (25°C)	64	upper 90th confidence bound (CB) on mean using half-lives of 6, 30, 33, 45, 52,59, 62, 69, and 105 days (MRID 40813501, 43154702)
Persistence in Soil (days)		
Soil photolysis half-life (25°C)	Stable	MRID 00153764
Aerobic soil metabolism half-life (25°C)	686	upper 90th confidence bound on mean using half-lives of 1272, 173, 589, 100, 225, 95.3 (MRID 4018510; and 49207701-03)
Field Dissipation		
Terrestrial field dissipation half-life	4-82 days in LA/MS field dissipation studies (5 of 6 studies half-life <20 days); 84-147 days in IN field dissipation	(MRIDs 45364705,45364706, 45163802, and 45136801)

3.2.1.1. Transport and Mobility

Parent pendimethalin was essentially immobile in loamy sandy (0.46% OC), sandy loam (0.93% OC), silt loam (2.73% OC), loam (2.21% OC), and silty clay loam (2.91% OC), and sandy clay loam (1.5% OC) soils from the U.S. with Freundlich K_{ads} values of 30, 110, 380, 301, and 854, respectively. K_{oc}s were 15000, 13000, 14100, 13700, and 29400, respectively. The 1/N values were 1.05, 1.08, 0.89, 1.20, and 0.83, respectively (MRID 00153765). In another study, parent pendimethalin was essentially immobile in loamy sand (0.87% OC), sandy loam (0.44% OC), sandy clay loam (0.67% OC), and sandy clay loam (1.5% OC) soils from Japan with Freundlich K_{ads} values of 61, 193, 153, and 285, respectively. K_{oc}s were 7011, 43863, 22835, and 19000 (MRID 43041901).

3.2.1.2. Degradation

In laboratory studies, pendimethalin was stable to hydrolysis (MRID 00106771). Pendimethalin degraded in an aqueous photolysis study with half-life of > 21 days at pH 7 (MRID 00153763).

Pendimethalin did not degrade on sandy loam soil exposed to artificial light at 25°C (MRID 00153764).

Microbial degradation of pendimethalin in aerobic soil is slow. Pendimethalin degraded under aerobic soil conditions with a half-lives range 95.3 to 1272 days (MRID 40951510; and 49207701-03). The nonvolatile degradates identified were CO_2; 2,6-dinitro-3,4-xylidine (CL 84,846); 4-[(1-ethylpropyl)amino]-3,5-dinitro-o-toluic acid (CL 99,900); and 4-[(l-ethylpropyl)amino]-2-methyl-3,5-dinitro-benzyl alcohol.

Under aerobic aquatic conditions, pendimethalin degraded slowly. Pendimethalin degraded with half-life range from 24.1 days in water-silt loam sediment system, and 41.4 days in water-sand sediment system (MRID 47385201). Only CO_2 was accounted for (no other metabolites).

Pendimethalin degrades slowly due to anaerobic aquatic metabolism with a half-life of 64.2 days (upper 90 percentile confidence bound on mean; MRID 43154702). There were many metabolites detected in the extracts of the water and sediment from nonsterile samples, but none of the metabolites accounted for greater than 10% of the initial dose of radioactivity.

3.2.1.3. Field Studies

Terrestrial field dissipation data (MRIDs 45364705,45364706, 45163802, and 45136801) that are consistent with laboratory data have also been provided. In an Indiana field dissipation study, the half-lie range from 84-147 days. However, in field dissipation studies in Louisiana (LA) and Mississippi (MS), the half-lives ranged from 4 to 82 days, with most studies containing half-lives of <20 days. The difference in half-lives between LA/MS and Indiana can be attributed to the soil and climatic differences between the two locations. No leaching was observed in the field dissipation studies, which is consistent with mobility studies which indicated that pendimethalin is essentially immobile in all soils studied. Soil samples were not analyzed for transformation products.

3.2.1.4. Monitoring Data

California Department of Pesticide Regulation

In 2008, the California Department of Pesticide Regulation initiated an urban monitoring study to determine the pesticides present in urban runoff, and to assess the differences of water-body type (receiving waters vs. storm drains) and seasonal conditions (baseflow vs. stormwater) on pesticide concentrations. Four metropolitan areas were chosen for monitoring sites: Sacramento, San Francisco Bay, Orange County, and San Diego. Each urban area consists of four to seven sampling sites representing a mix of receiving waters and storm drains. Water samples were collected during baseflow and storm events. The samples were analyzed for 41 insecticides (pyrethroids, carbamates, organophosphates, fipronil and degradates) and 21 herbicides (dinitroanilines, photosynthetic, and auxin herbicides). Sediment samples were only collected during baseflow events and analyzed for pyrethroids. Preliminary results show fipronil (and degradates) were the most prevalent insecticides followed by carbaryl and malathion; several pyrethroids were also detected in sediment. **The most frequently detected herbicides** were the auxin herbicides followed by diuron and **pendimethalin**. Overall, there are more pesticide detections in stormwater versus baseflow, with storm drains exhibiting higher concentrations than receiving waters. http://www.cdpr.ca.gov/docs/emon/surfwtr/swposters/study249.pdf (accessed on January 24, 2017).

The Surface Water Protection Program (SWPP) conducts monitoring studies in several major urban and agricultural areas in the state. Between 2010 and 2014, almost 200 chemicals were monitored. Differences exist between urban and agricultural (ag) monitoring programs. More pesticides have been monitored in ag areas (182 pesticides) than in urban areas (140 pesticides). Herbicides (57 urban; 67 ag) are most frequently monitored, followed by insecticides (46 urban; 61 ag), pesticide degradates (29 urban; 35 ag), and fungicides (6 urban; 14 ag). A few fumigants and synergists are also monitored (2 urban; 5 ag). Pesticides detected frequently are cause for concern, especially those with a higher potential for aquatic toxicity. Of herbicides in agricultural monitoring, metolachlor, **pendimethalin**, oxyfluorfen, diuron, and trifluralin **are frequently detected** at concentrations that have potential toxicity to aquatic organisms. In urban areas, only diuron and pendimethalin meet these criteria.
http://cwss.org/uploaded/media_pdf/4412-41_M2_Ruud,%20N.%20and%20Ensminger,%20M.%20Ground_Surf%20Water%20Abstract%202016%20CWSS.pdf (accessed on January 24, 2017).

USGS NAWQA

A search of the USGS National Water Information System (NWIS) turned no data on pendimethalin.

3.2.1.5. Bioconcentration Data

Pendimethalin accumulated readily in bluegill sunfish with bioconcentration factors (BCFs) of 1400X in edible portions, 5800X in non-edible portions, and 5100X in whole fish. Of labeled ^{14}C-pendimethalin taken up by fish, depuration of 87-91% of the ^{14}C-residues occurred by 14 days post exposure (MRID 00156726, 00158235).

3.2.1.6. Environmental Degradates & Unextracted Residues

Appendix B lists the maximum degradate amounts measured in degradation studies. The aerobic soil study (MRID 49207701), and the anaerobic soil study (MRID 49207705) showed that un extracted residues reached a maximum of 71% of applied radioactivity. In both studies data showed that the un extracted residues are likely to be strongly sorbed to soil or sediment. Thus; and as a consequence they are not likely to be extractable with additional solvents, then the un extracted residues are considered bound or strongly sorbed to soil or sediment.
If uncertainty remains as to whether the un extracted residues should be considered residues of concern, then the un extracted residues are conservatively treated, in the interim, as residues of concern, unless they are shown to exclude the identified residues of concern.

3.2.2. Measures of Aquatic Exposure

3.2.2.1. Surface Water Exposure to Pendimethalin

Using EFED's standard suite of models, surface water EECs were generated for pendimethalin for the registered uses on various crops. The Pesticide in Water Calculator (PWC) estimates pesticide concentrations in surface water and groundwater bodies that result from pesticide applications to land. The calculator was designed as a regulatory tool for users in the USEPA's Office of Pesticide Programs and in the Pest Management Regulatory Agency of Health Canada. The calculator uses the Pesticide Root Zone Model (PRZM) (version 5.0+) and the Variable Volume Water Model (VVWM).

Exposure estimates generated using the standard pond are intended as surrogates for potential concentrations in a wide variety of vulnerable water bodies, including prairie potholes, playa lakes, vernal pools, other wetlands, man-made and natural ponds, and ephemeral and first-order streams. Multiple site-specific factors will tend to make such water bodies more or less vulnerable than the standard pond. Static water bodies that have larger ratios of pesticide-treated drainage area to water body volume are generally expected to have higher peak concentrations than the standard pond's EECs. Such water bodies may be smaller in size, and/or have larger drainage areas. However such water bodies may be more likely to overflow and discharge pesticide in their effluent, whereas the EFED standard pond has no discharge. As watershed size increases, it becomes increasingly unlikely that the entire watershed is planted with a single crop that is all treated simultaneously with a pesticide. Headwater streams may have peak concentrations that are higher than those predicted for the standard pond, but such concentrations will likely persist for only short periods of time or distance, as they are carried downstream and diluted with water originating elsewhere.

The general chemical and environmental fate data for pendimethalin listed in **Table 4 and 8** were used for generating model input parameter values for PWC. Chemical specific and model input values were chosen in accordance with current divisional guidance (USEPA, 2009). Modeling was conducted to generate EECs in surface water of pendimethalin using PWC. Modeling results are reported in **Table 9**.

Table 8. PWC input parameter values for Pendimethalin registered uses*.

Input Parameter	Value	Source	Comments
Application Rate in lbs a.i./A	See Table 4		
Application Method	See Table 4		
Molecular Mass (g/mol)	281.3		http://sitem.herts.ac.uk/aeru/iupac/Reports/511.htm
Spray Drift Fraction	12.5 (aerial default) 6.2 (ground default)	USEPA 2013	

Application Efficiency	0.99 (ground) 0.95 (aerial)		Guidance for Selecting Input parameters in Modeling the Environmental Fate and Transport of Pesticides (v. 2.1; 2009)
Application date [method G: Ground A: Aerial]	Perennial warm-season forage grasses (early spring) [A] African marigold (within 60 days of planting) [G] Alfalfa (early spring) [A] Bush berries (pre crop plant) [G] Brassica Head and Stem (pre planting) [A] Citrus Fruit Trees (pre transplanting) [G] Corn (pre crop emergence) [A] Cotton (15 days pre planting) [A] Grain Sorghum (early post crop emergence) [A] Sugarcane (60 days pre planting)[A] Hops (June-July) [A] Tobacco (within 60 days of trans planting tobacco) [G]	EPA Reg No. 241-418	
Vapor Pressure (Torr)	9.4×10^{-6}	TRID 470246023	
Solubility in Water at 25°C (mg/L)	0.30	TRID 470246023	
Organic carbon partitioning coefficient Koc (ml/g)	17,040	MRID 00153765, 43041901	Represents the mean of 5 values
Aerobic Soil Metabolism Half-life (days)	686	(MRID 40951510, 49207701-03)	upper 90th confidence bound on mean using half-lives of 1272, 173, 589, 100, 225, 95.3
Aerobic Aquatic Metabolism Half-life (days)	51.5	MRID 47385201	upper 90th confidence bound on mean using half-lives of 24.1, and 41.4 (MRID 47385201)

Anaerobic Aquatic Metabolism Half-life (days)	64	MRID 49591202	upper 90th confidence bound (CB) on mean using half-lives of 6, 30, 33, 45, 52,59, 62, 69, and 105 days
Hydrolysis Half- life (days) @ pH 7	Stable	MRID 00106777	
Aqueous Photolysis - Half-life (days) @ pH 7	21	MRIDs 00153763, 43808201	Dark corrected half-life

*Representative of highest and lowest application rate for crops listed in Table 4, were modeled., as shown in Table8.

Table 9. Surface Water Modeling Results for Pendimethalin Use On Various Crops.

Crop Group* [application method, aerial or ground]	Model Scenario	1-in-10 year Surface Water (µg/L)		
		peak daily	peak 21-day average	peak 60-day average
Perennial warm-season forage grasses. [A]	CAalfalfa	27.2	4.58	2.47
Artichoke [A] Asparagus (post-harvest)	MIAsparagusSTD	26.7	4.75	2.68
African marigold [G]	CAnurserySTD_V2	10.5	3.13	2.28
Fruiting Vegetables (tomato), [A] Fruiting Vegetables (all others) (pre planting) Green Onions	FLtomatoSTD_V2	14.0	2.66	1.77
Mint (pepper, spear) [A]	ORmintSTD	13.8	2.45	1.41
Potato (pre crop emergence) [A] Edamame (vegetable soybean) Grain Sorghum [A] Peanut (at planting) [A] Forage Legumes	MEpotatoSTD KSsorghumSTD NCpeanutSTD	12.6 12.2 10.8	4.45 3.48 2.52	3.16 2.44 1.82
Leaf Lettuce Leafy Brassica Greens [A] Brassica Head and Stem Vegetables (Broccoli)	FLcabbageSTD	6.95	1.36	0.76
Citrus Fruit Trees (bearing and nonbearing) [A]	FLcitrusSTD	21.3	4.56	3.36

Dry Bulbs (garlic, onions, shallots) Lentils (when dry bulb onions or dry bulb [A] shallots have 2 to 9 true leaves)	GAOnion_WirrigSTD	16.9	5.15	4.10
Strawberry [A] Strawberry (and other low-growing berries (pre transplanting)	FLstrawberry_WirrigSTD	14.3	4.36	3.09
Carrot [A] (pre crop emergence) Carrot grown for seed production	FLcarrotSTD	15.1	3.74	2.29
Date palm tree, Fig (nonbearing only) Olive trees (bearing and nonbearing), Pomegranate trees (bearing and nonbearing), Tree Nuts (bearing and nonbearing) [G] (preplant)	CAfruit_WirrigSTD GAPecansSTD	20.2 27.2	3.60 6.96	2.09 4.44
Pome Fruit Trees (bearing and nonbearing), Stone Fruit Trees (bearing and nonbearing), [G]	NCappleSTD MICherriesSTD	14.8 17.7	4.45 5.47	3.03 ()3.87
Grape (bearing and nonbearing) Small Fruit Climbing Vines (bearing and nonbearing) [G] (any time after fall harvest)	NYGrapesSTD	31.9	9.82	7.42
Corn (field, pop, seed, sweet) [A] Sunflower	MScornSTD	25.8	7.40	4.79
Bushberries (bearing and nonbearing) [G] Caneberries (bearing and nonbearing) Juneberry Tree (bearing and nonbearing)	ORberriesOP	23.9	8.35	5.60
Cotton [A]	MScottonSTD	24.0	7.45	4.64
Sugarcane [A]	FLsugarcaneSTD LAsugarcaneSTD	34.2 44.3	9.68 11.3	7.20 8.48
Hops [A]	ORhopsSTD	28.4	5.57	3.33
Tobacco [G]	NCtobaccoSTD	6.01	1.41	0.83

NA: Not available
*: for the following crops, these available scenarios were modeled. The scenario produced the highest EECs are listed in this table
Corn scenarios include NE, NC, MS, MN, KS, IN, and IL. MS corn scenario gave the highest EECs.
Nursery scenarios include: CA, MI, and NJ. CA nursery scenario gave the highest EECs.
Stone fruit: GA peaches and MI cherries.
Pome fruit: NC, OR, PA-apple, and Washington orchards.
Nut tree: GA pecan, CA almond, and OR filbert.
Potato: Idaho and Main potato
Grape: NY and CA grape
Shaded text denotes the highest EEC from the use on crops.

For the various crops modeled, acute EECs range from 6 to 44 ppb, and it is important to note that across all of the modeling output, EECs do not vary greatly.

Selected model input and output files supporting these values are presented in **Appendix A**.

3.2.3. Measures of Terrestrial Exposure

3.2.3.1. Ingestion of Surface Residues by Birds and Mammals

Terrestrial wildlife exposure estimates are typically calculated for birds and mammals, emphasizing a dietary exposure route for uptake of pesticide active ingredients. Avian exposures are considered surrogates for exposures to terrestrial-phase amphibians and reptiles. For exposure to terrestrial organisms, such as birds and mammals, pesticide residues on food items are estimated, based on the assumption that organisms are exposed to pesticide residues in a given exposure use pattern. For pendimethalin, application methods for the registered uses include foliar spray. For terrestrial animals, the T-REX model (Version 1.5.2)[2] is used to calculate dietary- and dose-based EECs of pendimethalin for mammals and birds feeding on the site of application. Input values for T-REX include the maximum single application rates, number of applications, and retreatment interval for a given use pattern. In this assessment, EFED uses a default foliar dissipation half-life of 35 days as an input for terrestrial exposure modeling in T-REX. Additionally, foliar dissipation half-life values between 1 and 35 days were explored as inputs for terrestrial exposure modeling in T-REX.

Upper-bound Kenaga nomogram values based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994) are used to derive EECs for pendimethalin exposures to terrestrial mammals and birds based on dietary- and dose-based exposures from foliar applications of pendimethalin**.** A one-year time period is simulated. Consideration is given to different types of feeding strategies for mammals and birds, including herbivores, insectivores and granivores. For dose-based exposures, three weight classes of mammals (15, 35, and 1000 g) and birds (20, 100, and 1000 g) are considered. For more information on estimating exposure to terrestrial organisms, see the T-REX User's Guide[3]. EECs derived based on mean Kenaga nomogram values were also selectively evaluated.

3.2.3.2. Runoff and Spray Drift to Terrestrial and Semi-Aquatic Plants

TERRPLANT (Version 1.2.2)[4] is used to calculate EECs for non-target plants that inhabit dry and semi-aquatic areas. In this assessment, exposure to non-target plants is calculated based on the potential runoff and spray drift of foliar applications of pendimethalin and potential runoff after soil and seed treatment applications. TERRPLANT does not account for particulate drift.

The spray drift model AgDrift version 2.1.1 is also used to provide bounds defining the spatial extent of risk concern resulting from off-field drift at currently registered pendimethalin application rates.

[2] http://www.epa.gov/oppefed1/models/terrestrial/
[3] http://www.epa.gov/oppefed1/models/terrestrial/trex/t_rex_user_guide.htm
[4] http://www.epa.gov/oppefed1/models/terrestrial/

Bioaccumulation

KABAM ($\underline{K}_{OW}$ (based) Aquatic BioAccumulation Model) is used to estimate potential bioaccumulation of hydrophobic organic pesticides in freshwater aquatic food webs and subsequent risks to mammals and birds via consumption of contaminated aquatic prey. KABAM is composed of two parts: 1) a bioaccumulation model estimating pesticide concentrations in aquatic organisms and 2) a risk component translating exposure and toxicological effects of a pesticide into risk estimates for mammals and birds consuming contaminated aquatic prey.

The bioaccumulation portion of KABAM relies on a pesticide's octanol-water partition coefficient (K_{OW}) to estimate uptake and elimination constants through respiration and diet of aquatic organisms in different trophic levels. Pesticide tissue concentrations in aquatic organisms are calculated for different trophic levels of a food web through diet and respiration.

In the risk component of KABAM, pesticide concentrations in aquatic organisms are used to estimate dose- and dietary-based exposures and associated risk quotients for mammals and birds consuming aquatic organisms. The methods used in the risk component of KABAM are consistent with EFED's current modeling approach for assessing risks to terrestrial mammals and birds described in USEPA 2004a, as implemented in the T-REX model.

The default model ecosystem for KABAM is defined as the EFED standard pond scenario for the Exposure Analysis Modeling System (EXAMS). The standard pond has two compartments: a water column and a benthic area. The water column is 20,000,000 liters in volume and the benthic area has a volume of 500,000 liters. The standard pond receives pesticides in runoff (dissolved in water and sorbed onto eroded soil) and spray drift from a 10-ha treatment field that is immediately adjacent to the pond. The treatment field is represented by various scenarios (in this case, LA sugarcane) using the PWC. The meteorological data corresponding to the selected PWC scenario can influence the runoff of a pesticide into the standard pond and also the water temperature of the pond environment.

As indicated in **Table 3** and its associated text in **Section 3**, pendimethalin has the potential to bioconcentrate in aquatic organisms, and there is also some potential to biomagnify in terrestrial organisms. The potential for bioaccumulation of pendimethalin is examined in this risk assessment. Because pendimethalin has a fairly high log K_{OW} (5.18) and the chemical may be persistent in water (aqueous photolysis half-life of 42 days) and sediments (>10 days for aquatic metabolism), there could be a potential for bioaccumulation. The maximum bioconcentration factor is 5100x for whole fish and the depuration rate is fairly slow (MRIDs 00156726 and 00158235).

Bioaccumulation will be assessed using the results from bioaccumulation in fish studies, as well as the KABAM model (K_{OW} (based) Aquatic BioAccumulation Model, version 1.0, 2009), adjusting for biotransformation rates. KABAM is used to estimate potential bioaccumulation of hydrophobic organic pesticides in freshwater aquatic ecosystems and risks to mammals and birds consuming aquatic organisms which have bioaccumulated these pesticides. Monitoring data and biotransformation rates in terrestrial species will also be evaluated, to assess the potential for bioaccumulation in terrestrial food webs.

3.3. Ecological Effects Characterization

The receptor is the biological entity that is exposed to the stressor (EPA, 1998). Due to the outdoor uses of pendimethalin, the types of receptors that may be exposed include both aquatic and terrestrial receptors, such as birds, reptiles, mammals, amphibians, freshwater and estuarine/marine fish, non-target terrestrial and aquatic invertebrates and terrestrial and aquatic plants. The stressors in this case are pendimethalin. Spray drift and runoff exposures are expected for both ground and aerial applications of pendimethalin. Consistent with the process described in the Overview Document (USEPA, 2004), this problem formulation uses a surrogate species approach in its evaluation of pendimethalin. Toxicological data generated from surrogate test species, which are intended to be representative of broad taxonomic groups, are used to extrapolate to potential effects on a variety of species (receptors) included under these taxonomic groupings.

Tables 10 and 11 provide a summary of the taxonomic groups and the surrogate species tested to help understand potential acute and chronic ecological effects of pendimethalin to these non-target taxonomic groups.

Terrestrial Animals

A summary of the most sensitive endpoints from the available toxicity studies conducted with terrestrial species is presented in **Table 10**.

Table 10 Summary of most sensitive endpoints from submitted terrestrial toxicity studies for pendimethalin.

Species (common name)	Taxa Represented	Endpoint	Concentration	Test Substance (% a.i.)	Reference/ Classification	Acute Toxicity Classification
Rattus norvegicus (Laboratory Rat)	Mammals	LD_{50}	1050 mg a.i./kg-bw	TGAI	MRID# 00026657 Acceptable	Slightly Toxic
		NOAEL	52 mg a.i./kg/day	TGAI	MRID# 41725203 Acceptable	Not Applicable
		LOAEL	125 mg a.i./kg/day			
Mallard duck (*Anas platyrhynchos*)	Birds, terrestrial-phase amphibians, and reptiles	LD_{50}	1421 mg a.i./kg bw	TGAI	MRID# 00059739 Acceptable	Slightly Toxic
Bobwhite quail (*Colinus virginianus*)		LC_{50}	4187 mg a.i./kg diet	TGAI	MRID# 00059739 Acceptable	Practically non-toxic
Mallard duck (*Anas platyrhynchos*)		NOAEL	141 mg a.i./kg-diet	TGAI	MRID# 44907601 Acceptable	Not Applicable
		LOAEL	1410 mg a.i./kg-diet	TGAI		Not Applicable

Apis mellifera (Honey bee)	Terrestrial invertebrates	Contact LC_{50}	>49.8 µg a.i./bee	TGAI	MRID# 0009980 Acceptable	Practically non-toxic

Mammals

The Agency's rat acute oral assessment endpoint for risk assessment purpose shows the LD_{50} to be 1250 mg/kg (male) and 1050 mg/kg (female) (MRID 00026657). Pendimethalin is considered to be slightly toxic to mammals on an acute oral basis.

A 2-generation reproduction study (MRID 41725203) with pendimethalin was reviewed by HED. The parental systemic NOAEL was 25 mg/kg/day (500 **ppm),** based on decreased body weight gain and food consumption at the LOAEL of 125 mg/kg/day (2500 **ppm).** The reproductive/offspring NOAEL is 25 mg/kg/day (500 **ppm),** based on decreases in the number of pups born and pup weight at the LOAEL of 125 mg/kg/day (2500 **ppm).** Parental and reproductive NOAELs and LOAELs were based on a generic ratio (1:20) of dietary intake of chemical.

The HED Cancer Peer Review Committee classified pendimethalin as a "Group C" (possible human) carcinogen, based on thyroid follicular cell adenomas in rats. The committee recommended a non-quantitative approach (non-linear, RfD approach) since mode of action studies are available that demonstrate that the thyroid tumors are due to a thyroid-pituitary imbalance, and also since pendimethalin was shown to be non- mutagenic in mammalian somatic cells and germ cells.

Birds

Two sub-acute LC_{50} dietary avian studies and one acute LD_{50} oral acute avian study using the technical pendimethalin were submitted to the Agency. For the LC_{50} dietary studies, the LC_{50} for the bobwhite quail is 4187 ppm and the mallard duck is >4640 ppm. For the acute LD_{50} for the mallard, the LD_{50} is 1421 mg/kg-bw. A passerine study with zebra finch (*Taeniopygia guttata*; MRID 49574901) was also submitted. No effects were noted with an LD_{50}: >1000 mg ai/kg; this study did not test high enough to definitively rule out potential risk to passerines.

The endpoint selected for the assessment is the bobwhite quail's LC_{50} of 4187 ppm (MRID 00026674) and the mallard's LD_{50} of 1421 mg/kg-bw (00059739).

Pendimethalin technical is categorized as slightly toxic on a subacute dietary and acute oral basis to birds. No avian studies using formulated product have been submitted to the Agency.

Two avian reproduction studies were submitted to the Agency. No treatment related effects were observed in the bobwhite quail and the LOAEL is greater than 1410 ppm. The mallard duck study (MRID 44907601) showed the parameter of 14-day survivor bodyweight was reduced at 1410 ppm. The NOAEL for the mallard study is 410 ppm. No other treatment related effects were observed. This study is classified as acceptable.

Terrestrial Invertebrates

An acute oral bee toxicity study (MRID 00051271 or 00108773) was submitted to the Agency. This study was authored by Dr. Atkins in 1974. The species tested is the honey bee, *Apis mellifera.* The LD_{50} acute oral is greater than 49.8 µg/bee with no mortality observed at the highest tested dose. Pendimethalin is classified as practically non-toxic to the honey bee.

Additionally, an acute contact and acute oral study (MRID 49207707) has been received by the Agency and is under review. In this study, both the acute oral LD_{50} and the acute contact LD_{50} were >100 µg ai/bee.

Aquatic Animals

A summary of the most sensitive endpoints from the available toxicity studies conducted with aquatic animals is presented in **Table 11**.

Table 11. Summary of most sensitive endpoints from submitted aquatic toxicity studies for pendimethalin.

Exposure Scenario	Species	Exposure Duration	Toxicity Reference Value	Effects	Reference	Toxicity Category
Freshwater Fish						
Acute	Rainbow trout (*Oncorhynchus mykiss*)	96 hours	LC_{50} = 138 µg a.i./L	Mortality	MRID 00046291 Acceptable	Highly Toxic
Chronic	Fathead minnow (*Pimephales promelas*)	288 days	NOAEC = 6.3 µg a.i./L LOAEC = 9.8 µg ai/L	Reduced egg production	MRID 00037940 Acceptable	NA
Freshwater Invertebrates						
Acute	*Daphnia magna*	96 hours	EC_{50} = 280 µg a.i./L	Mortality	MRID 00059738 Acceptable	Very Highly Toxic
Chronic	*Daphnia magna*	21 days	NOAEC = 14.5 µg a.i./L LOAEC = 17.2 µg ai/L	Reduced production of young	MRID 00100504 Supplemental	NA
Benthic Organisms						
	Midge (Chironomus riparius)	10 days	NOAEC > 203 mg a.i./kg LOAEC = 203 mg a.i./kg	No effects	MRID 47891601 Supplemental	NA
Estuarine/Marine Fish						
Acute	Sheepshead minnow (*Cyprinidon*	96 hours	LC_{50} = 710 µg a.i./L	Mortality	MRID 00131774 Acceptable	Very Highly Toxic

	variegates)					
Chronic	Sheepshead minnow	34 days	NOAEC = 10 µg a.i./L LOAEC = 23 µg ai/L	Growth (length)	MRID 49530702 In review	
Estuarine/Marine Invertebrates						
Acute	Eastern Oyster *Crassostrea virginica*	96 hours	LC_{50} = 210 µg a.i./L	Mortality	MRID 00131772 Acceptable	Very Highly Toxic
Chronic	No data available					

Freshwater Fish

Three acute freshwater studies using technical grade pendimethalin are available (MRIDs 00037778, 0003778, and 00046291). Species studied include the bluegill sunfish, rainbow trout, and channel catfish with LC_{50} values of 199 ppb, 138 ppb and 418 ppb respectively. In addition, seven acute freshwater studies using formulated product are available (MRIDs 00037927, 00037927, 00037927, 00037927, 00037927, 00037927, and 00131773). Species studied include the bluegill sunfish, rainbow trout, and channel catfish and LC_{50} values ranged from 520 ppb formulation to 94,400 ppb formulation (220 ppb and 28,747 ppb active ingredient, respectively), indicating that the formulated products are less toxic to freshwater fish than the technical grade pendimethalin. The available data suggests that pendimethalin is very highly toxic to freshwater fish on an acute basis.

One chronic freshwater fish study (MRID00037940) was submitted to the Agency. This study is a fathead minnow (*Pimephales promelas)* full life cycle study using technical grade pendimethalin. The 288-day NOAEC is 6.3 ppb (0.0063 ppm). The NOAEC is based on reduction of egg production. The LOAEC = 9.8 ppb (0.0098 ppm) is based on reduction of egg production. Reduced hatchability was also observed at 22 and 43 ppb. The acute toxicity of pendimethalin to fathead minnow is unknown and chronic data are not available for rainbow trout, the most sensitive species for which acute data is available

Estuarine/Marine Fish

There is one study available on the acute toxicity of technical grade pendimethalin and the formulation AC 92, 533 to the sheepshead minnow (*Cyprinodon variegatus*, MRID 00131774; Acceptable). The study reported a 96-hour LC_{50} value of 707 ppb (C.I. 552-907 ppb) for technical grade pendimethalin and a 96-hour LC_{50} value of 1700 ppb (C.I. 1230-3560 ppb) for the formulation.

The 34-day chronic toxicity of pendimethalin to the early life-stage of sheepshead minnow

(*Cyprinodon variegatus*; MRID 49530702) was studied under flow-through conditions. Fertilized sheepshead minnow embryos (120/level, <24 hours old) were exposed at mean-measured concentrations were <1.1 (<LOQ, control), 10, 23, 54, 88, and 210 µg ai/L, respectively. The overall NOAEC and LOAEC were 10 and 23 µg ai/L, respectively, based on treatment-related effects on growth (wet weight). This study is under review.

Freshwater Invertebrates

Three acute freshwater invertebrate studies were submitted to the Agency: two studies using the waterflea *Daphnia magna* and one using crayfish, *Procambarus simulans* (MRIDS 00059738, 00071123, and 00153772 respectively).

A *Daphnia magna* study using technical grade pendimethalin had an EC_{50} of 280 ppb (C.I. 230-330) and is considered to be an acceptable study. The other *Daphnia magna* study used the formulation containing 45.6% active ingredient with the EC_{50} = 5.1 ppm (5100 ppb) formulation. This study is considered to be acceptable for a formulated study. Acute toxicity of pendimethalin technical to freshwater invertebrates is categorized as ranging from moderately toxic to highly toxic. Pendimethalin formulation is categorized as moderately toxic.

One chronic freshwater invertebrate study (MRID 00100504) was submitted to the Agency. This study is a *Daphnia magna* life cycle study using a technical grade pendimethalin. The 21-day NOAEC is 14.5 ppb (0.0145 ppm). The NOAEC is based on reduced production of Daphnia. LOAEC = 0.0172 ppm (17.2 ppb). Mortality was observed in the study with 100% mortality at the 2 highest dose levels of 35.8 and 74.2 ppb. No appreciable mortality observed at 3 lowest concentration levels of 4.3, 8.2, and 14.5 ppb. Reduction of productivity of 50% occurred at 22.1 and 17.5 ppb concentration levels.

Estuarine/Marine Invertebrates

Two acute freshwater invertebrate studies are available for pendimethalin. An acceptable study with the eastern oyster (*Crassostrea virginica*, MRID 00131772) used technical grade and formulated pendimethalin (AC 92, 533). The study reported a 48-hour EC_{50} value of 210 ppb (C.I. 160-340 ppb) for technical grade pendimethalin and a 48-hour EC_{50} value of 450 ppb for the formulation, indicating that pendimethalin is highly toxic to oysters.

In addition, an acceptable study tested the toxicity of technical grade pendimethalin and the formulation AC92, 533 to pink shrimp (*Penaeus duorarum*, MRID 00131775). The study had a 96-hour LC_{50} value of 1.6 ppm (C.I. 1.2-2.2 ppm) for technical grade pendimethalin and a 96-hour LC_{50} value of 11 ppm (C.I. 8.9-16 ppm) for the formulated product. This study suggests that pendimethalin is moderately toxic to pink shrimp.

Benthic Invertebrates

A 28-day spiked sediment study (MRID 47891601) for the non-biting midge (*Chironomus riparius*) has been submitted and reviewed. Although the study is scientifically sound based on methods described in the non-guideline OECD Guideline 218 ("Sediment-Water Chironomid

Toxicity Test Using Spiked Sediment"), it is classified as 'supplemental' because NOAEC and LOAEC values were not established, and the highest test concentration was well below the limit concentration of 1,000 mg a.i./kg sediment. Based on the results of the study, no treatment-related effects on mortality, emergence, or development rates were observed at the highest mean-measured treatment level in sediment of 203 mg a.i./kg dw. In addition, total organic carbon (TOC) was not reported in this study. Without information on TOC it is not possible to determine whether the lack of treatment related effects were due to a relative insensitivity to the test substance or whether pendimethalin bound to the available organic carbon such that is was not bioavailable for the test organism. Concentrations of pendimethalin were measured in sediment, overlying water, and pore water at 0 and 28 days. In general, concentrations of pendimethalin remained largely associated with the sediment phase; the highest pendimethalin concentration in overlying water was measured at 80 μg a.i./L, and no quantifiable levels (<50 μg a.i./L) were detected in pore water.

Three other benthic invertebrate studies have been submitted to the Agency. While these studies currently remain under review, primary review suggest that while effects on some individuals occur, there are no biologically relevant effects on any single concentration in any of the studies when compared to controls. The studies are MRID 49603001, *Leptochirus plumulus*; MRID 49530704, *Hyalella azteca*; and MRID 49530703, *Chironomus tentans*. Final reviews will be completed before the interim decision is made.

Plants

Tier II terrestrial plant toxicity testing was originally conducted with the TGAI, rather than the TEP as required by the non-target plant protection data requirements specified in 40 CFR Part 158. These data have been submitted and reviewed. However, the original TGAI studies remain the most sensitive of the available endpoints and are used in this risk assessment. Based on the available Tier II seedling emergence and vegetative vigor toxicity data for the TGAI, ryegrass and lettuce are the most sensitive monocot and dicot plants, respectively. It is important to note that all ten test species showed effects >25% in the seedling emergence test, whereas two of the ten test species (including radish and cucumber, both dicots) showed no effect in the vegetative vigor test at the highest treatment level of 4.0 lbs a.i./A. This study did not test the maximum application rate for currently registered uses of pendimethalin. In addition, use of the TGAI data may underestimate toxicity to plants as the TEP may include adjuvants or surfactants that increase the toxicity of the parent compound. The TEP data received represents only one of many registered pendimethalin products, so it is unclear if these data (MRIDs 49862601 and 49862602) are truly representative of the toxicity of formulated pendimethalin. The most sensitive IC_{25} and NOAEC values for ryegrass and lettuce, based on the available TGAI data, are bolded in **Table 12**.

Table 12. Summary of Tier II Terrestrial Plant Toxicity Data for Pendimethalin.

Crop	Species	IC_{25} (lbs a.i./A)	NOAEC (lbs a.i./A)	Most sensitive parameter
Seedling Emergence				
Monocots	Oat	1.0	0.25	Plant height

	Ryegrass	**0.02**	**0.01**	**Dry weight**
	Corn	0.68	0.5	Plant height
	Onion	0.08	0.06	Dry weight
Dicots	Soybean	4.7	2.0	Dry weight
	Lettuce	**0.09**	**0.063**	**Dry weight**
	Radish	0.86	0.13	Plant height
	Tomato	0.2	0.13	Dry weight
	Cucumber	2.4	0.25	Plant height
	Cabbage	0.44	0.25	Plant height
Vegetative Vigor				
Monocots	Oat	0.78	0.5	Dry weight
	Ryegrass	**0.034**	**0.0008**	**Dry weight**
	Corn	2.8	2.0	Plant height
	Onion	0.56	0.5	Plant height
Dicots	Soybean	0.27	0.13	Dry weight
	Lettuce	**0.10**	**0.003**	**Dry weight**
	Radish	>4.0	4.0	NA
	Tomato	0.5	0.13	Dry weight
	Cucumber	>4.0	4.0	NA
	Cabbage	4.8	2.0	Dry weight

Aquatic plant toxicity data submitted to the Agency show a range of IC_{50} values from 5.2 ppb to >174 ppb. The most sensitive species tested are the green algae and marine diatom and the least sensitive species is the cyanobacteria (blue-green algae). With respect to aquatic vascular and non-vascular plants (**Table 13)**, duckweed (*Lemna gibba*) and the marine diatom (*Skeletonema costatum*) are most sensitive to pendimethalin with respective IC_{50} values of 5.6 µg a.i./L and 0.7 µg a.i./L.

Table 13. Summary of Most Sensitive Aquatic Plant Toxicity Data for Pendimethalin.

Species	Acute Toxicity			
	120-hr IC_{50} (µg a.i./L)	14-day IC_{50} (µg a.i./L)	NOAEC (µg a.i./L)	Endpoints (MRID)
Duckweed *Lemna gibba*	--	12.5	5.6	Reduced Frond Number (42137101)
Diatom *Skeletonema costatum*	5.2	--	0.7	Growth Inhibition (42372205)

ECOTOX

In addition to submitted data, available open literature will be used to evaluate the potential direct effects of pendimethalin to the terrestrial receptors identified in this section. This includes toxicity data on the technical grade active ingredient, and when available, formulated products.

A full ECOTOX search has been performed (2016), but no endpoints more sensitive were identified than those used in this risk assessment. However, the identified studies may provide more in-depth characterization information for future assessments, such as an endangered species assessment. The open literature studies were identified through EPA's ECOTOX database (http://cfpub.epa.gov/ecotox/), which employs a literature search engine for locating chemical toxicity data for aquatic life, terrestrial plants, and wildlife. The evaluation of data can also provide insight into the direct and indirect effects of pendimethalin on biotic communities from loss of species that are sensitive to the chemical and from changes in structure and functional characteristics of the affected communities.

Open literature toxicity data for other 'target' insect species (not including bees, butterflies, beetles, and non-insect invertebrates including soil arthropods and worms), which include efficacy studies, are not currently considered in deriving the most sensitive endpoint for terrestrial insects. Efficacy studies do not typically provide endpoint values that are useful for risk assessment (such as NOAEC, EC_{50}, etc.), but rather are intended to identify a dose that maximizes a particular effect (such as EC_{100}). Therefore, efficacy data and non-efficacy toxicological target insect data will not be included in the ECOTOX open literature search.

Incident Database Review

A review of the Incident Data System and Aggregate Incident databases for ecological incidents involving pendimethalin was completed on January 11, 2017. This database consists of exposure incident reports submitted to the EPA from 1994 to present. A search for incidents involving pendimethalin was also conducted in the American Bird Conservancy's Avian Incident Monitoring System (AIMS).

The reports are listed in order of certainty, from highly probable to unrelated. Incidents listed in EIIS are categorized by the likelihood that a particular pesticide is associated with that particular incident. These classifications include highly probable, probable, possible, unlikely, or unrelated. "Highly probable" incidents usually require carcass residues or clear circumstances regarding the exposure. "Probable" incidents include those where residue information was not available or circumstances were less clear than those for "highly probable". "Possible" incidents occur when multiple chemicals may have been involved and the contribution of an individual chemical is not obvious. An "unlikely" incident classification is given when a given chemical is considered nontoxic to the type of organism involved or the chemical was analyzed and not detected in samples. The "unrelated" category is used for incidents confirmed not to involve pesticides.

The number of reports listed in the EIIS database is believed to be only a small fraction of the total incidents involving organism mortality and damage caused by pesticides. Few resources are assigned to incident reporting. Reporting by states is only voluntary, and individuals discovering incidents may not be informed on the procedure of reporting these occurrences. Additionally, much of the database is generated from registrant-submitted incident reports. In addition, incident reports for non-target organisms typically provide information only on mortality events and plant damage incidents. Except for phytotoxic effects in terrestrial plants, sublethal effects for organisms such as reduced growth or impaired reproduction are rarely reported. Because of these logistical difficulties, EIIS is most likely a minimal representation of all pesticide-related ecological incidents.

Registrants are legally required to provide detailed reports of only "major" ecological incidents involving pesticides, while "minor" incidents are reported aggregately. Based on 40 CFR

§159.184, an ecological incident is considered major and must be submitted to the Agency by the registrant if any of the following criteria are met:

Fish or wildlife:
(A) Involves any incident caused by a pesticide currently in Formal Review[5] for ecological concerns.
(B) Fish: Affected 1,000 or more individuals of a schooling species or 50 or more individuals of a non-schooling species.
(C) Birds: Affected 200 or more individuals of a flocking species, or 50 or more individuals of a songbird species, or 5 or more individuals of a predatory species.
(D) Mammals, reptiles, amphibians: Affected 50 or more individuals of a relatively common or herding species or 5 or more individuals of a rare or solitary species.
(E) Involves effects to, or illegal pesticide treatment (misuse) of a substantial tract of habitat (greater than or equal to 10 acres, terrestrial or aquatic).
Plants:
(A) The effect is alleged to have occurred on more than 45 percent of the acreage exposed to the pesticide.

The EIIS database contained 70 major incidents involving pendimethalin. The reports included 65 terrestrial plant incidents, 2 fish incidents, and 2 avian incidents. With respect to the likelihood that pendimethalin caused the reported incidents, the certainty ranged from unlikely to highly probable. The majority of reported incidents were identified as probable or highly probable. Twenty-seven of the incidents resulted from registered uses, 4 were misuses, and the remaining use patterns are unknown.

The AIMS database contains 2 avian incidents involving pendimethalin, both of which are also captured in EIIS.

All other incidents are classified as 'minor'. All ecological incidents classified as 'minor' only need to be aggregately reported as quarterly counts of incidents by the registrant(s). Ecological incidents reported in aggregate reports include those categorized as 'minor fish and wildlife' (W-B), 'minor plant' (P-B), and 'other non-target' (ONT) incidents. 'Other non-target' incidents include reports of adverse effects to insects and other terrestrial invertebrates. For pendimethalin, the registrants have reported 4 minor fish and wildlife incidents, 1,035 minor plant incidents, and 3 "other non-target" incidents. Unless additional information on these aggregated incidents becomes available, they will be assumed to be representative of registered uses of pendimethalin in the risk assessment.

4. Risk Characterization

[5] Formal Review means Special Review, Rebuttable Presumption Against Registration (RPAR), FIFRA section 6(c) suspension proceeding, or FIFRA section 6(b) cancellation proceeding, whether completed or not.

4.1. Risk Estimation

This assessment of the labeled uses of pendimethalin relies on the deterministic RQ method to provide a metric of potential risks. The RQ provides a comparison of exposure estimates to toxicity endpoints (*i.e.*, estimated exposures divided by acute and/or chronic toxicity endpoints expressed in the same units as exposures, respectively). The resulting unitless RQ values, calculated in the Risk Estimation Section) are compared to the Agency's LOCs (see **Table**). The LOCs are used by the Agency to indicate when the use of a pesticide, as directed by the label, has the potential to result in exposure levels sufficient to cause adverse effects to non-target organisms. In this approach, RQs that exceed non-listed species LOCs necessarily also exceed the corresponding listed species LOCs. Acute risk LOCs are different for listed and non-listed taxa; however, the chronic LOC is 1.0 across all animals. For plants, unlike for animals, RQ values are not presented for acute versus chronic risk; instead, RQ values are presented for listed and non-listed species based on a comparison of a given EEC to NOAEL and IC_{25} values (for terrestrial plants) and EC_{50} values (for aquatic plants), respectively. The LOC for all plants is 1.0. A discussion of the RQ values for pendimethalin and of other information that provides context for the interpretation of potential risk to various taxa is presented in the Risk Description in **Section 4.2**. Risk quotients were estimated for maximum labeled rates.

One label, EPA Reg. No. 9198-191, was discovered to allow a maximum annual application rate up to 9.0 lbs a.i./A for use on warm season turf grasses. This rate is considerably higher than the maximum annual application rate allowed for all other pendimethalin use sites and end-use products of 6.0 lbs a.i./A. While this higher rate was not directly assessed in this document, RQs would be generally increased by roughly 33% in areas where this product is used at that maximum rate. If this rate is intentional and not an error on the label for EPA Reg. No. 9198-191, it will be modeled following the public comment period in an addendum.

4.1.1 Aquatic Taxa

Water column

Acute exposure RQs for the most sensitive of the available fish endpoints indicate LOC exceedances for listed species (0.05) for all use patterns, with a maximum RQ of 0.32 (**Table 14**). All RQs are below the acute LOC for non-listed species (0.5). The available estuarine/marine fish endpoint also results in a marginal exceedance of the listed species LOC for the highest use rate alone (RQ=0.06). There are no exceedances of the chronic exposure LOC (1.0) for most use patterns. The exception is for the sugarcane use pattern, where the LOC is exceeded (RQ=**1.35**).

For aquatic invertebrates in the water column, acute RQs exceed the listed species LOC for all but the lowest use rates (leafy greens), but do not exceed the non-listed species LOC with the highest RQ of 0.16. The chronic LOC is not exceeded for any use pattern.

Table 14. Risk Quotients for aquatic exposure from selected use patterns[1].

Scenario	1-in-10 year Surface Water EECs (µg/L)		Chronic	Acute invertebrate	Chronic invertebrate

				Acute fish	fish	s	s
	peak daily average	peak 21-day average	peak 60-day average	Tox Endpoints			
				138 µg/L	6.3 µg/L	280 µg/L	14.5 µg/L
LA sugarcane	40.6	11.6	8.32	*0.32*	**1.35**	*0.16*	0.78
Cotton	24	7.45	4.64	*0.17*	0.74	*0.09*	0.51
Corn (field, pop, seed, sweet), Sunflower	25.8	7.4	4.79	*0.19*	0.76	*0.09*	0.51
Leaf Lettuce, Leafy Brassica Greens, Brassica Head and Stem Vegetables (Broccoli)	6.95	1.36	0.76	*0.05*	0.12	0.02	0.09
Strawberry (and other low-growing berries) (pre transplanting)	14.3	4.36	3.09	*0.10*	0.49	*0.05*	0.30
Turf (1 app @ 6 lbs)	40.5	6.62	3.29	*0.29*	0.52	*0.14*	0.46
Turf (2 app @ 3 lbs, 4 wk interval)	21.1	3.87	2.91	*0.15*	0.46	*0.08*	0.27

Bold indicates exceeds chronic risk LOC
Italics indicates exceeds acute listed species LOC
[1] Please refer to Table 6 for use patterns and rates crosswalk; specific uses not included should be interpreted with scenarios of similar use rates.

Benthic Zone

Based on the available studies, pendimethalin appears to pose low risk to benthic organisms.

Aquatic plants

Use of pendimethalin poses a risk to aquatic plant species. Vascular aquatic plant RQs range as high as 3.5 for nonlisted species and 7.9 for listed species. Nonvascular plant RQs range as high as 8.5 for nonlisted species and 63.3 for listed species (**Table 15**). However at this time there are no listed aquatic nonvascular plants.

Table 15. Risk Quotients for aquatic exposure from selected use patterns[1].

Scenario	1-in-10 year Surface Water (µg/L)	Vascular *Lemna gibba*	Nonvascular *Skeletonema costatum*

	peak daily average	Endpoints			
		Nonlisted IC_{50} 12.5 µg/L	**Listed NOAEC 5.6 µg/L**	**Nonlisted IC_{50} 5.2 µg/L**	**Listed NOAEC 0.7 µg/L**
LA sugarcane	44.3	**3.5**	**7.9**	**8.5**	**63.3**
Cotton	24	**1.9**	**4.3**	**4.6**	**34.3**
Corn (field, pop, seed, sweet), Sunflower	25.8	**2.1**	**4.6**	**5.0**	**36.9**
Leaf Lettuce, Leafy Brassica Greens, Brassica Head and Stem Vegetables (Broccoli)	6.95	0.6	**1.2**	**1.3**	**9.9**
Strawberry (and other low-growing berries) (pre transplanting)	14.3	**1.1**	**2.6**	**2.8**	**20.4**

[1] Please refer to Table 6 for use patterns and rates crosswalk; specific uses not included should be interpreted with scenarios of similar use rates.

4.1.2 Terrestrial Taxa

Avian Risk

Acute dose-based exposure RQs exceed the acute risk LOC (0.5) for the highest use patterns for several forage and size classes, and the listed species (0.1) for all use patterns for some size classes and forage types (**Table 16**). Dietary-based RQs do not exceed the LOC for any use pattern. There are numerous exceedances of the chronic exposure LOC, up to 10-fold. Size class is not considered for chronic RQ calculation.

Table 16. Avian acute and chronic Risk Quotients for various size classes and forage types[1].

Scenario	Forage Class	Avian Acute RQs			Chronic RQs
		Size Class (grams)			
		20	100	1000	
2 lbs a.i./A, 3 apps, 5 d interval	Short Grass	**1.46**	**0.65**	*0.21*	**9.28**
	Tall Grass	**0.67**	*0.30*	0.09	**4.25**
	Broadleaf plants	**0.82**	*0.37*	*0.12*	**5.22**
	Fruits/pods	0.09	0.04	0.01	0.58
	Arthropods	**0.57**	*0.26*	0.08	**3.63**

	Seeds	0.02	0.01	0.00	NA
6 lbs a.i./A, single app	Short Grass	**1.60**	**0.72**	*0.23*	**10.21**
	Tall Grass	**0.73**	*0.33*	*0.10*	**4.68**
	Broadleaf plants	**0.90**	*0.40*	*0.13*	**5.74**
	Fruits/pods	*0.10*	0.04	0.01	0.64
	Arthropods	**0.63**	*0.28*	0.09	**4.00**
	Seeds	0.02	0.01	0.00	NA
4 lbs a.i./A, single app	Short Grass	**1.07**	*0.48*	*0.15*	**6.81**
	Tall Grass	*0.49*	*0.22*	0.07	**3.12**
	Broadleaf plants	**0.60**	*0.27*	0.09	**3.83**
	Fruits/pods	0.07	0.03	0.01	0.43
	Arthropods	*0.42*	*0.19*	0.06	**2.67**
	Seeds	0.01	0.01	0.00	
2 lbs a.i./A, single app	Short Grass	**0.53**	*0.24*	0.08	**3.40**
	Tall Grass	*0.24*	*0.11*	0.03	**1.56**
	Broadleaf plants	*0.30*	*0.13*	0.04	**1.91**
	Fruits/pods	0.03	0.01	0.00	0.21
	Arthropods	*0.21*	0.09	0.03	**1.33**
	Seeds	0.01	0.00	0.00	NA
1 lb a.i./A, single app	Short Grass	*0.27*	*0.12*	0.04	**1.70**
	Tall Grass	*0.12*	0.05	0.02	0.78
	Broadleaf plants	*0.15*	0.07	0.02	0.96
	Fruits/pods	0.02	0.01	0.00	0.11
	Arthropods	*0.10*	0.05	0.01	0.67
	Seeds	0.00	0.00	0.00	NA

Bold indicates exceedance of nonlisted LOC (acute=0.5; chronic=1.0)
Italics indicates exceedance of listed LOC (acute=0.05)
[1] Please refer to Table 6 for use patterns and rates crosswalk; specific uses not included should be interpreted with scenarios of similar use rates.

Mammalian Risk

Pendimethalin has few acute risk non-listed species LOC exceedances, though there are listed species LOC exceedances in all modeled scenarios. Pendimethalin presents a relatively higher risk profile from chronic exposure (**Table 17**). The acute non-listed species exceedances are limited to small and medium size animals that forage on short grass in the higher usage scenarios. However, there are chronic dose-based LOC exceedances across scenarios and size classes, with the highest RQ exceeding the LOC 12-fold (*i.e.* RQ=12). It should be noted that there are no exceedances of any kind for mammals foraging on the 'fruits/pods' or 'seeds' dietary classes. Dietary-based chronic exposure RQs are as high **1.26** and **1.38** for the short grass forage class in two high-end scenarios presented, but do not exceed for any other forage class or scenario.

Table 17. Mammalian acute and chronic risk quotients for various size classes and forage types[1].

Scenario	Forage Class	**Dose-based RQs** (Dose-based EEC/LD50 or NOAEL)					
		Small mammal 15g		**Medium mammal 35g**		**Large mammal 1000g**	
		Acute	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**
2 lbs a.i./A, 3 apps, 5 d interval	Short Grass	**0.54**	**10.92**	*0.46*	**9.32**	*0.25*	**5.00**
	Tall Grass	*0.25*	**5.00**	*0.21*	**4.27**	*0.11*	**2.29**
	Broadleaf plants	*0.30*	**6.14**	*0.26*	**5.24**	*0.14*	**2.81**
	Fruits/pods	0.03	0.68	0.03	0.58	0.02	0.31
	Arthropods	*0.21*	**4.28**	*0.18*	**3.65**	*0.10*	**1.96**
	Seeds	0.01	0.15	0.01	0.13	0.00	0.07
6 lbs a.i./A, single app	Short Grass	**0.59**	**12.01**	**0.51**	**10.26**	*0.27*	**5.50**
	Tall Grass	*0.27*	**5.51**	*0.23*	**4.70**	*0.12*	**2.52**
	Broadleaf plants	*0.33*	**6.76**	*0.29*	**5.77**	*0.15*	**3.09**
	Fruits/pods	0.04	0.75	0.03	0.64	0.02	0.34
	Arthropods	*0.23*	**4.71**	*0.20*	**4.02**	*0.11*	**2.15**
	Seeds	0.01	0.17	0.01	0.14	0.00	0.08
4 lbs a.i./A, single app	Short Grass	*0.40*	**8.01**	*0.34*	**6.84**	*0.18*	**3.67**
	Tall Grass	*0.18*	**3.67**	*0.16*	**3.14**	0.08	**1.68**
	Broadleaf plants	*0.22*	**4.50**	*0.19*	**3.85**	*0.10*	**2.06**
	Fruits/pods	0.02	0.50	0.02	*0.43*	0.01	*0.23*
	Arthropods	*0.16*	**3.14**	*0.13*	**2.68**	0.07	**1.44**
	Seeds	0.01	0.11	0.00	0.10	0.00	0.05
2 lbs a.i./A, single app	Short Grass	*0.20*	**4.00**	*0.17*	**3.42**	0.09	**1.83**
	Tall Grass	0.09	**1.84**	0.08	**1.57**	0.04	0.84
	Broadleaf plants	*0.11*	**2.25**	*0.10*	**1.92**	0.05	**1.03**
	Fruits/pods	0.01	0.25	0.01	0.21	0.01	0.11
	Arthropods	0.08	**1.57**	0.07	**1.34**	0.04	0.72

	Seeds	0.00	0.06	0.00	0.05	0.00	0.03
1 lb a.i./A, single app	Short Grass	*0.10*	**2.00**	0.08	**1.71**	0.05	0.92
	Tall Grass	0.05	0.92	0.04	0.78	0.02	0.42
	Broadleaf plants	0.06	**1.13**	0.05	0.96	0.03	0.52
	Fruits/pods	0.01	0.13	0.01	0.11	0.00	0.06
	Arthropods	0.04	0.78	0.03	0.67	0.02	0.36
	Seeds	0.00	0.03	0.00	0.02	0.00	0.01

[1] Please refer to Table 6 for use patterns and rates crosswalk; specific uses not included should be interpreted with scenarios of similar use rates.

Terrestrial Invertebrates

Insufficient data exist for evaluating the risk of pendimethalin to terrestrial invertebrates. The only available data point is an LD_{50} acute oral value > 49.8 μg/bee with no mortality observed at the highest tested dose. Pendimethalin is classified as practically non-toxic to the honey bee. Because the endpoint is nondefinitive, RQs are not calculated.

Non-target Terrestrial Plants

Runoff EECs for terrestrial plants were calculated using TERRPLANT (Version 1.2.2). RQ values for terrestrial plants are calculated using the most sensitive endpoints for monocot and dicot species in vegetative vigor and seedling emergence tests with pendimethalin. The potential for adverse effects to listed and non-listed species of terrestrial and semi-aquatic plants from exposure to pendimethalin is discussed in greater detail in the Risk Description (**Section 4.2**). In the risk description, the distance from the edge of the field where effects may occur due to exposure to spray drift is described. **Table 18** reports the RQ values from TERRPLANT for runoff; drift alone analysis with AgDRIFT is reported in Risk Description (p48).

Table 18. Risk Quotients for Non-target Terrestrial Plants Adjacent to Pendimethalin Use Sites[1].

Use	Plant Type	Listed Status	Risk Quotients	
			Dry	Semi-Aquatic
6.0 lbs a.i./A				
	Monocot	non-listed	**18.00**	**45.00**
	Monocot	listed	**36.00**	**90.00**
	Dicot	non-listed	**4.00**	**10.00**
	Dicot	listed	**5.71**	**14.29**
4 lbs a.i./A				
	Monocot	non-listed	**12.00**	**30.00**
	Monocot	listed	**24.00**	**60.00**
	Dicot	non-listed	**2.67**	**6.67**
	Dicot	listed	**3.81**	**9.52**
1.0 lbs a.i./A				
	Monocot	non-listed	**3.00**	**7.50**
	Monocot	listed	**6.00**	**15.00**

	Dicot	non-listed	0.67	**1.67**
	Dicot	listed	0.95	**2.38**

Bold values indicate LOC (1.0) exceedance
*Runoff RQ values for nontarget plants are based on the seedling emergence NOAEC of 0.01 lb a.i./A for monocots and 0.063 lb a.i./A for dicots. Corresponding IC_{25} values were estimated to be 0.02 lb a.i./A for monocots and 0.09 lb a.i./A for dicots.
[1] Please refer to Table 6 for use patterns and rates crosswalk; specific uses not included should be interpreted with scenarios of similar use rates.

4.3. Risk Description

This preliminary risk assessment of the labeled uses of pendimethalin relies on the deterministic RQ method to provide a metric of potential risks. RQs for registered pendimethalin uses exceed LOC values for:

- fish (and aquatic-phase amphibians) and invertebrates
- aquatic vascular and non-vascular plants
- birds (and terrestrial-phase amphibians)
- mammals
- terrestrial plants

Toxicity data available for adult honey bees suggest risk is unlikely on an acute contact basis but the dataset is incomplete.

One product label, EPA Reg. No. 9198-191, was discovered to allow a maximum annual application rate up to 9.0 lbs a.i./A for use on warm season turf grasses. This rate is considerably higher than the maximum annual application rate allowed for all other pendimethalin use sites and end-use products of 6.0 lbs a.i./A. While this higher rate was not directly assessed in this document, RQs would be generally increased by roughly 33% in areas where this product is used at that maximum rate. If this rate is intentional and not an error on the label for EPA Reg. No. 9198-191, it will be modeled following the public comment period in an addendum. One label, EPA Reg. No. 9198-191, was discovered to allow a maximum annual application rate up to 9.0 lbs a.i./A for use on warm season turf grasses. This rate is considerably higher than the maximum annual application rate allowed for all other pendimethalin use sites and end-use products of 6.0 lbs a.i./A. While this higher rate was not directly assessed in this document, RQs would be generally increased by roughly 33% in areas where this product is used at that maximum rate. If this rate is intentional and not an error on the label for EPA Reg. No. 9198-191, it will be modeled following the public comment period in an addendum.

4.3.1 Risk to Aquatic Organisms

Aquatic Exposure

Surface water EECs resulting from applications of pendimethalin are estimates of exposure for representative use patterns. Application practices were modeled using the maximum annual application rates. Finally, scenario selection was conservatively performed by modeling runoff prone soils that drain to a small pond without an outlet.

Aquatic Animals

Risk to freshwater and estuarine/marine fish and invertebrates is generally below the established acute non-listed and chronic levels of concern and according to this analysis adverse effects to non-listed aquatic animals are not anticipated to result from registered uses of pendimethalin. However, acute listed species LOCs are exceeded for all use patterns and the fish chronic LOC is exceeded for crops using the maximum application rate of 6.0 lbs a.i./A. Two 'major' fish incidents are associated with pendimethalin in the IDS database; 4 'minor' incidents are also reported.

There are also exceedances for benthic organisms (LOC=1.0) for the sugarcane use patterns. The exceedances occur in the bulk sediment endpoints for *Chironomus dilutus*, which is a species that exhibits some ingestion of sediment. Current guidelines require the endpoints to be organic matter adjusted, which are not reported in the available study. Given the high Koc and high log Kow of pendimethalin, benthic organisms that ingest sediment are potentially at risk from higher-end use patterns. These organisms are often foundational species in aquatic food chains and disruption in their populations could impact higher trophic-level organisms. Additionally, as discussed later, higher trophic-level organism may accumulate pendimethalin via dietary exposure, therefore even exposure below toxic levels may impact aquatic communities.

Aquatic Plants

Based on available data, there appears a likelihood for adverse effects to listed and non-listed vascular and nonvascular aquatic plants. RQ values for listed and non-listed nonvascular aquatic plants range from **1.3** to **63**. RQ values for listed and non-listed vascular aquatic plants range from 0.6 to **7.9**. Serving as the autotrophic base for many food webs, indirect effects to affected ecosystems are possible.

4.3.2. Risk to Terrestrial Organisms

Terrestrial Exposure

To evaluate the potential for terrestrial exposure from the multiple registered uses of pendimethalin, application practices were modeled by using maximum application rates for certain scenarios. These scenarios represent a bounding of all of the registered uses of pendimethalin. Exposure was estimated using upper-bound Kenaga values from T-REX version 1.5.2.

Birds and Mammals

Pendimethalin is classified as slightly toxic to birds on an acute oral exposure basis. On a subacute dietary basis, pendimethalin is classified as practically non-toxic to avian species. Pendimethalin is categorized as slightly toxic to mammals on an acute oral exposure basis. Chronic exposure related effects were observed in both avian and mammalian reproduction studies.

In this assessment, RQs based on acute oral exposure to birds exceed the acute risk LOC of 0.5 for several forage/size class categories. The number of exceedances is tightly correlated to application rate, with, the high rate of 6.0 lbs a.i./A posing the greatest risk. The maximum acute exposure RQ is 1.63, over 3X the LOC. In addition, numerous forage/size class combinations exceed the acute listed species LOC of 0.1, even at the lowest label application rate of 1.0 lbs a.i./A. While several RQs calculated based on a subacute dietary exposure to birds exceed LOCs for risk to listed birds, none exceed the acute non-listed bird LOC.

Considering chronic dietary exposure, RQs for birds exceed the chronic risk LOC for at least one dietary class at the maximum label rate for all registered uses. The highest RQ, based on 6.0 lbs a.i./A and for short grass foragers exceeds the LOC by a factor of 10. The EECs exceed the NOAEC for up to 80 days.

For mammals, the acute dose-based RQ values for small mammals using short grass forage exceed the acute non-listed species LOC of 0.5 for the two highest modeled use patterns; however, all size classes of mammals exceed the LOC for acute risk to listed (RQ≥0.1) species for short grass, tall grass, broadleaf plants/small insects, and arthropods across multiple use patterns.

Chronic dietary RQs for mammals exceed the chronic risk LOC of 1.0 up to 12-fold for short grass, tall grass, broadleaf plants, and arthropods for all use sites at maximum application rates. Foragers of fruits and pods as well as granivores did not exceed the LOC for any use patterns.

The potential for risk to birds and mammals from proposed foliar uses were evaluated in this assessment using the default foliar dissipation half-life of 35 days, since no additional data were available to determine the decline in pendimethalin residues in dietary items. A reduction in half-life would not reduce overall risk since most of the scenarios modeled were a single application. However, the duration of exceedances would be reduced to some degree if the actual foliar dissipation half-life were to be demonstrated to be less than the default value.

Terrestrial Invertebrates

In a 48-hour acute contact toxicity test in which young adult honey bees were exposed to pendimethalin, the LD_{50} value for the contact test was >49.8 μg ai/bee. Based on these limited data, pendimethalin is categorized as practically nontoxic to honey bees on an acute contact basis. RQs are not calculated based on nondefinitive endpoints. However, For a 6 lb/A rate, the contact EEC would be 16.2 ug/bee—well below the non-definitive acute contact endpoint. For a 6 lb/A rate, the oral dose (if you end up using the acute oral data) would be 192 ug/bee/day (6 lb/A*110 ug/g*0.292 g/day), which is roughly 2x the non-definitive acute oral LD_{50}

Since pendimethalin is used on citrus and other insect pollinator-attractive crops used by some beekeepers to produce honey, the proximity of bee colonies to pendimethalin use areas may be high. Pendimethalin is taken up into plants; however, it is unknown whether it is transported in the xylem or phloem and whether bees may be exposed to pendimethalin taken up into plant materials such as pollen, nectar, *etc.*

There are no reported incidents of bee kills for pendimethalin. However, the absence of bee kill incident data cannot be construed as the absence of incidents.

Based on the acute contact toxicity studies, risk to individual adult honey bees would be considered low; however, a full dataset is not available to fully evaluate risk to honey bees (*i.e.*, acute and chronic oral toxicity to adults and acute and chronic toxicity to larvae). Pollinator risk assessment guidance has recently been finalized and recommends the following honey bee data be available for a Tier I screening level risk assessment for honey bees:

- acute oral toxicity to adult honey bees;
- acute oral toxicity to larval honey bees;
- chronic oral toxicity to adult honey bees; and,
- chronic oral toxicity to larval honey bees.

Until these data are available, the risk to honey bees cannot be fully evaluated. Risk to individual adult honey bees exposed in their diet to pendimethalin could not be evaluated. Additionally, data are not available to evaluate potential effects to brood.

Non-target terrestrial plants

As expected with an herbicide, nontarget plants are likely to be adversely affected by use of pendimethalin. This likelihood is supported by the numerous plant incidents reported to the Agency. Based on runoff EECs, matched with seedling emergence endpoints, RQs for sheet flow runoff (one acre to one acre) run as high as 18 for non listed plants and 36 for listed plants (based on ryegrass). RQs for channelized flow (10 acres to one acre) are as high as 45 and 90, respectively.

The terrestrial spray drift distance (*i.e.*, the distance from the edge of the field where spray drift exposure could result in RQs that exceed LOCs) for risk to terrestrial plants was explored for representative application rates for pendimethalin using both ground and aerial application scenarios (**Table 20**). AgDRIFT modeling was conducted using model defaults. Ground application was modeled with low boom application; high boom application will exhibit greater distances. Increasing the droplet spectra (*i.e.* coarser droplets) for any of the scenarios will decrease the distance off the field. The listed species LOC is exceeded at distances greater than 1000 feet from the edge of field for all scenarios except for ground applications up to 2 lb a.i./A.

Table 20. Spray Drift Distance Where Terrestrial Plant RQs do not Exceed LOCs[1]

Application Rate (lb a.i./A)	Distance to no LOC exceedance (feet)*	
	Terrestrial Plant	
	Monocot Vegetative Vigor *Ryegrass* IC_{25} = 0.034 lb a.i./A (NOAEC=0.0008)	**Dicot Vegetative Vigor** *Lettuce* IC_{25}=0.10 lb a.i./A (NOAEC=0.003)
Ground application		
6	180*	56*
4	115*	36*
2	52*	20 (682)
1	26*	10 (351)
Aerial application		
6	>1000*	568*
4	>1000*	364*
2	554*	184*

1	272*	98*

* Listed species greater than 1000 feet
[1] Please refer to Table 6 for use patterns and rates crosswalk; specific uses not included should be interpreted with scenarios of similar use rates.

Bioaccumulation potential

In the risk component of KABAM, pesticide concentrations in aquatic organisms are used to estimate dose- and dietary-based exposures and associated risk quotients for mammals and birds consuming aquatic organisms. The methods used in the risk component of KABAM are consistent with EFED's current modeling approach for assessing risks to terrestrial mammals and birds described in USEPA 2004a, as implemented in the T-REX model.

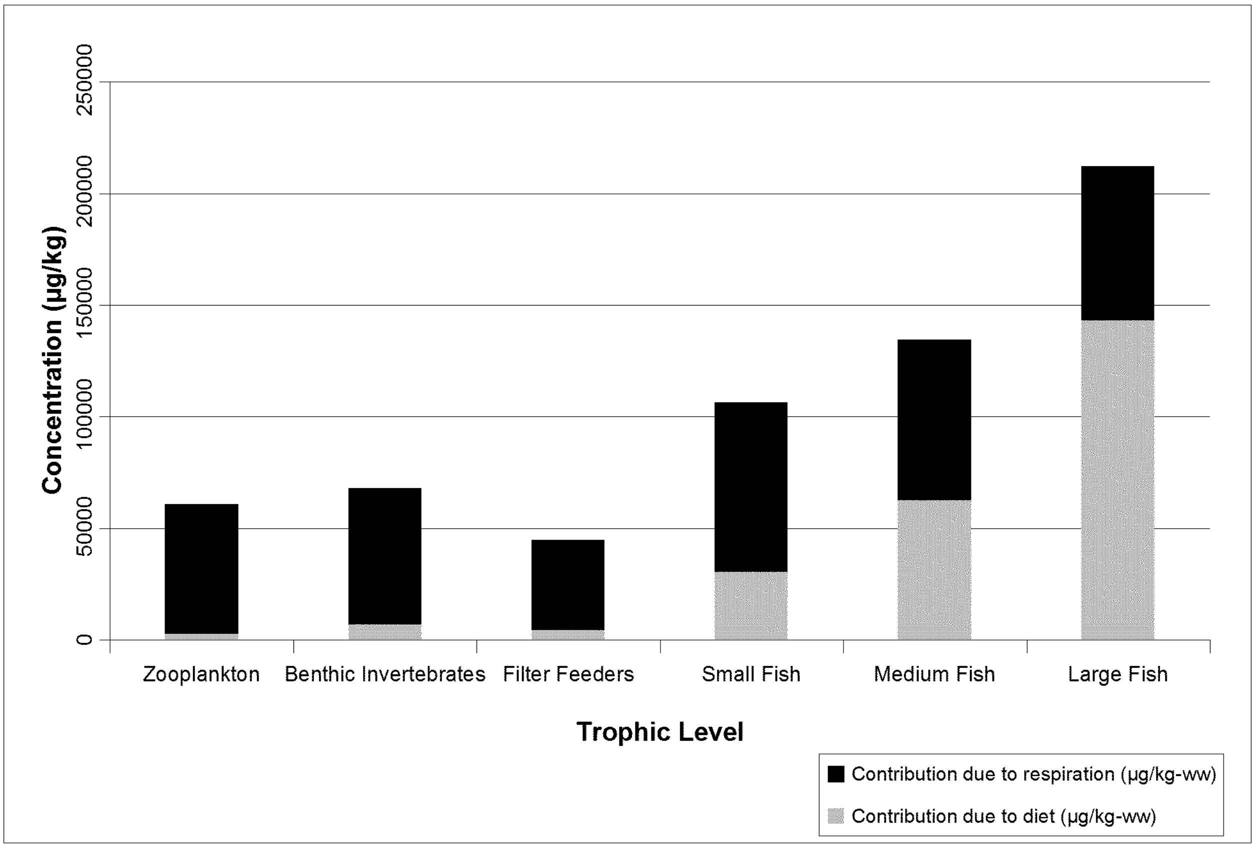


Figure 1. Total pesticide concentration per trophic level

Figure 1 identifies that as pendimethalin accumulates up trophic levels, a great portion of uptake is due to diet. Standard BCF studies only account for uptake through water column exposure. Therefore, while the available BCFs of 1400X in edible portions, 5800X in non-edible portions, and 5100X in whole fish are relatively high, they likely underestimate total accumulation in fish. Additionally, the depuration of 87-91% of the ^{14}C-residues which occurred by 14 days post exposure (while in clean water) are potentially overestimating the overall depuration rate for pendimethalin since feeding is a big contributor to pendimethalin bioconcentration. It is important to note that this modeling has been conducted assuming zero metabolism which likely lead to higher RQs.

Taken together, **Table 21** reports the modeled RQs for avian and mammalian surrogates consuming fish contaminated by pendimethalin. The river otter and white pelican both exceed the chronic exposure LOC (1.0) and the sandpiper exceeds the acute listed species LOC (0.05). Therefore, there is some concern for pendimethalin bioaccumulation effects on the food chain. However, as mentioned above, introducing a realistic metabolic rate would very likely lower these RQs below the LOC.

Table 21. Calculation of RQ values for mammals and birds consuming fish contaminated by pendimethalin.

Wildlife Species	Acute		Chronic	
	Dose Based	Dietary Based	Dose Based	Dietary Based
Mammalian				
fog/water shrew	0.018	N/A	0.364	0.065
rice rat/star-nosed mole	0.024	N/A	0.476	0.070
small mink	0.040	N/A	0.809	0.129
large mink	0.044	N/A	0.894	0.129
small river otter	0.048	N/A	0.962	0.129
large river otter	0.081	N/A	**1.641**	0.204
Avian				
sandpipers	**0.103**	0.018	N/A	0.520
cranes	0.006	0.020	N/A	0.588
rails	0.056	0.021	N/A	0.618
herons	0.010	0.024	N/A	0.719
small osprey	0.020	0.032	N/A	0.955
white pelican	0.013	0.051	N/A	**1.505**

5. Endocrine Disruptor Screening Program (EDSP)

As required by FIFRA and the Federal Food, Drug, and Cosmetic Act (FFDCA), EPA reviews numerous studies to assess potential adverse outcomes from exposure to chemicals. Collectively, these studies include acute, subchronic and chronic toxicity, including assessments of carcinogenicity, neurotoxicity, developmental, reproductive, and general or systemic toxicity. These studies include endpoints which may be susceptible to endocrine influence, including effects on endocrine target organ histopathology, organ weights, estrus cyclicity, sexual maturation, fertility, pregnancy rates, reproductive loss, and sex ratios in offspring. For ecological hazard assessments, EPA evaluates acute tests and chronic studies that assess growth, developmental and reproductive effects in different taxonomic groups. As part of the Preliminary Problem Formulation for Registration Review (USEPA 2012), EPA reviewed these data and selected the most sensitive endpoints for relevant risk assessment scenarios from the existing hazard database. However, as required by FFDCA section 408(p), pendimethalin is subject to the endocrine screening part of the Endocrine Disruptor Screening Program (EDSP).

EPA has developed the EDSP to determine whether certain substances (including pesticide active and other ingredients) may have an effect in humans or wildlife similar to an effect produced by a "naturally occurring estrogen, or other such endocrine effects as the Administrator may designate." The EDSP employs a two-tiered approach to making the statutorily required determinations. Tier 1 consists of a battery of 11 screening assays to identify the potential of a chemical substance to interact with the estrogen, androgen, or thyroid (E, A, or T) hormonal systems. Chemicals that go through Tier 1 screening and are found to have the potential to interact with E, A, or T hormonal systems will proceed to the next stage of the EDSP where EPA will determine which, if any, of the Tier 2 tests are necessary based on the available data. Tier 2 testing is designed to identify any adverse endocrine-related effects caused by the substance, and establish a dose-response relationship between the dose and the E, A, or T effect.

Under FFDCA section 408(p), the Agency must screen all pesticide chemicals. Between October 2009 and February 2010, EPA issued test orders/data call-ins for the first group of 67 chemicals, which contains 58 pesticide active ingredients and 9 inert ingredients. A second list of chemicals identified for EDSP screening was published on June 14, 2013[1] and includes some pesticides scheduled for registration review and chemicals found in water. Neither of these lists should be construed as a list of known or likely endocrine disruptors. Pendimethalin is not on Lists 1 or 2. For further information on the status of the EDSP, the policies and procedures, the lists of chemicals, future lists, the test guidelines and Tier 1 screening battery, please visit our website[2].

6. Federally Threatened and Endangered (Listed) Species Concerns

In November 2013, the EPA, along with the U.S. Fish & Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS) (collectively, the Services), and the U.S. Department of Agriculture (USDA) released a summary of their joint Interim Approaches for assessing risks to listed species from pesticides. The Interim Approaches were developed jointly by the agencies in response to the National Academy of Sciences' (NAS) recommendations and reflect a common approach to risk assessment shared by the agencies as a way of addressing scientific differences between the EPA and the Services. The NAS report outlines recommendations on specific scientific and technical issues related to the development of pesticide risk assessments that EPA and the Services must conduct in connection with their obligations under the Endangered Species Act (ESA) and FIFRA.

[1] See http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0477-0074 for the final second list of chemicals.
[2] Available: http://www.epa.gov/endo/

The joint Interim Approaches were released prior to a stakeholder workshop held on November 15, 2013. In addition, the EPA presented the joint Interim Approaches at the December 2013 Pesticide Program Dialogue Committee (PPDC) and State-FIFRA Issues Research and Evaluation Group (SFIREG) meetings, and has held several stakeholder workshop, allowing additional opportunities for stakeholders to comment on the Interim Approaches. As part of a phased, iterative process for developing the Interim Approaches, the agencies will also consider public comments on the Interim Approaches in connection with the development of upcoming Registration Review decisions. The details of the joint Interim Approaches are contained in the white paper "*Interim Approaches for National-Level Pesticide Endangered Species Act Assessments Based on the Recommendations of the National Academy of Sciences April 2013 Report*," dated November 1, 2013.

Given that the agencies are continuing to develop and work toward implementation of the Interim Approaches to assess the potential risks of pesticides to listed species and their designated critical habitat, this preliminary risk assessment for pendimethalin does not contain a complete ESA analysis that includes effects determinations for specific listed species or designated critical habitat. Although EPA has not yet completed effects determinations for specific species or habitats, for this preliminary assessment EPA conducted a screening-level assessment for all taxa of non-target wildlife and plants that assumes for the sake of the assessment that listed species and designated critical habitats may be present in the vicinity of the application of pendimethalin. This preliminary risk assessment will allow EPA to focus its future evaluations on the types of species where the potential for effects exists once the scientific methods being developed by the agencies have been fully vetted. This screening-level risk assessment for pendimethalin indicates potential risks of direct effects to listed dicot terrestrial plants, monocot terrestrial plants, aquatic vascular plants, mammals, birds, and terrestrial invertebrates for registered pendimethalin use sites. Listed species of semi-aquatic plants may also be affected through indirect effects because of the potential for direct effects on listed and non-listed species upon which such species may rely. Potential direct effects on listed dicot terrestrial plants, monocot terrestrial plants, aquatic vascular plants, mammals, birds, and terrestrial invertebrates from the use of pendimethalin may be associated with modification of Primary Constituent Elements (PCEs) of designated critical habitats, where such designations have been made. Once the agencies have fully developed and implemented the scientific methods necessary to complete risk assessments for endangered and threatened (listed) species and their designated critical habitats, these methods will be applied to subsequent analyses for pendimethalin as part of completing this registration review.

7. References

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USEPA. 2016. Screening Level Usage Analysis (SLUA) of Pendimethalin (108501). U.S. Environmental Protection Agency, Office of Pesticide Programs, Biological and Economic Analysis Division.

8.1 Submitted Product Chemistry and Environmental Fate Studies

161-1 Hydrolysis

161-1 Hydrolysis

MRID		Citation Reference
46287	See 106777 below	Zulalian, J.; Eisner, S.K. (1974) Prowl Herbicide: A Study on the Behavior of 14?C-Labeled CL 92,553 in an Hydrolytic Environ- ment: Project No. 2-463. (Unpublished study received Sep 27, 1974 under 5F1556; submitted by American Cyanamid Co., Prince- ton, N.J.; CDL:094674-A)
46296	**2037434**	Zulalian, J.; Fasinski, R.; Eisner, S.K. (1973) CL 92,553: Metabo- lism VII. Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) on Exposure to Sunlight in Water and on Glass and Soil Surfaces: Report No. 2-463. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by American Cyanamid Co., Princeton, N.J.; CDL:094673-R)
109914	See above	Zulalian, J.; Fasinski, R.; Eisner, S. (1973) CL 92,553: Metabo- lism VII. Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) on Exposure to Sunlight in Water and on Glass and Soil Surfaces: PD-M 10:912-958. (Unpublished study received on unknown date under 4G1451; submitted by American Cyanamid Co., Princeton, NJ; CDL:094672-D)
106777	**2037438**	Study in Hydrolytic environment

161-2 Photodegradation-water

MRID		Citation Reference
153763	**2037455**	Sanders, P. (1985) Prowl Herbicide, Pendimethalin (AC 92,553): Photodegradation in Water: Project No. 0166: Report No. PD-M Volume 22-36. Unpublished study prepared by American Cyanamid Co. 32 p.
43808201	Mentioned in RED chapter	Ta, C. (1995) Aqueous Photolysis of AC 92,553: Lab Project Number: ENV 95-028: E-95-04. Unpublished study prepared by American Cyanamid Co. 99 p.
05001076	**2037439**	Open lit on photodecomposition – 11 herbibcides

46296		Zulalian, J.; Fasinski, R.; Eisner, S.K. (1973) CL 92,553: Metabo- lism VII. Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) on Exposure **to Sunlight in Water** and on Glass and Soil Surfaces: Report No. 2-463. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by American Cyanamid Co., Princeton, N.J.; CDL:094673-R)

161-3 Photodegradation-soil

MRID		Citation Reference
46296	**2037434**	Zulalian, J.; Fasinski, R.; Eisner, S.K. (1973) CL 92,553: Metabo- lism VII. Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) on Exposure to Sunlight in Water and on Glass and Soil Surfaces: Report No. 2-463. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by American Cyanamid Co., Princeton, N.J.; CDL:094673-R)
109914	See above	Zulalian, J.; Fasinski, R.; Eisner, S. (1973) CL 92,553: Metabo- lism VII. Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) on Exposure to Sunlight in Water and on Glass and Soil Surfaces: PD-M 10:912-958. (Unpublished study received on unknown date under 4G1451; submitted by American Cyanamid Co., Princeton, NJ; CDL:094672-D)
153764	**2037456**	Mangels, G. (1985) Prowl Herbicide, Pendimethalin (AC 92,553): Photodegradation on Soil: Project No. 0166: Report No. PD-M Volume 22-35. Unpublished study prepared by American Cyanamid Co. 27 p.

162-1 Aerobic soil metabolism

MRID		Citation Reference
46282	**2037414 Summary 2037315**	Barringer, D.F., Jr.; Haugwitz, M.I.; Eisner, S.K. (1974) CL 92,553: Metabolism XIII. The Behavior of CL 92,553 (Prowl Herbicide) in Soil, Part III. Anaerobic Studies: Project No. 2- 463. (Unpublished study received Sep 27, 1974 under 5F1556; submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094475-I)
40185104	**2037461**	Lavin, M.; Cranor, W. (1987) Aerobic Soil Metabolism of [Carbon 14]-Pendimethalin: Lab. Rept. No. 33731. Unpublished study pre- pared by Analytical Bio-Chemistry Laboratories, Inc. 677 p.

162-2 Anaerobic soil metabolism

MRID		Citation Reference
151795 or 137706	2037518 pg 2	Mangels, G. (1984) Prowl Herbicide, Pendimethalin (CL 92,553): Anaerobic Metabolilsm in Soil from a Rice Field: Project NO. 0470: Rept. No. PD-M Vol. 21-2.1. Unpublished study prepared by American Cyanamid Co. 29 p.

40185105	**2037462**	Lavin, M.; Cranor, W. (1987) Anaerobic Soil Metabolism of [Carbon 14]-Pendimethalin: Lab. Rept. No. 33732. Unpublished study pre- pared by Analytical Bio-Chemistry Laboratories, Inc.

162-3 Anaerobic aquatic metab.

MRID		Citation Reference
40813501	**2037483**	Sanders, P. (1988) Pendimethalin (AC 92,553): Anaerobic Aquatic De- gradation in Soil from a Rice Field: Laboratory Project ID PD-M- 25-25. Unpublished study prepared by American Cyanamid Co. 53 p.
43154701	Response	Mangels, G.; Ahmed, Z. (1994) Pendimethalin Registration Standard--**Response to EFGWB Review.** Unpublished study prepared by American Cyanamid Co. 88 p.
43154702	No DER but summarized in REDs 2038941	Mangels, G. (1991) Pendimethalin (AC 92, 553): Anaerobic Aquatic Degradation in Static Canadian Pond Water: Lab Project Number: PD-M 28-5: E-89-30: 0466. Unpublished study prepared by American Cyanamid Co. 117 p.

162-4 or 835.4300 Aerobic aquatic metab.

MRID		Citation Reference
47385201	**2081628**	Ebert, D. (2008) Degradation of Pendimethalin (BAS 455 H) in Water/Sediment Systems Under Aerobic Conditions: Final Repost. Project Number: 169996, 2004/1022517. Unpublished study prepared by BASF Aktiengesellschaft. 75 p.

163-1 Leach/adsorp/desorption

MRID		Citation Reference
46288	**2037416 Summary 2037315**	Barringer, D.F., Jr.; Haugwitz, M.I.; Jakowlew, S.B.; et al. (1974) CL 92,553: A Study of the Leaching of CL 92,553 (Prowl Herbi- cide) from Four Different Soil Types: Project No. 2-463. (Un- published study received Sep 27, 1974 under 5F1556; submitted by American Cyanamid Co., Princeton, N.J.; CDL:094674-B)
46289	**2037417 Summary 2037315**	O'Grodnick, J.S.; Dupre, G.D. (1974) Leaching Characteristics of ^14IC-Prowl^(R)I and Its Degradation Products following Aging in Princeton Sandy Loam Soil under Greenhouse Conditions: Report No. 74003-1. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Bio/dynamics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:094674-C)
46290	**2037418 Summary 2037315**	Dupre, G.D. (1974) Runoff Characteristics of ^14IC-Prowl^(R)I Ap- plied to Silt Loam Soil under Greenhouse Conditions: Report No. 74004. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Bio/dynamics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:094674-D)
46296		Zulalian, J.; Fasinski, R.; Eisner, S.K. (1973) CL 92,553: Metabo- lism VII. Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) on Exposure to Sunlight in Water and on Glass and **Soil Surfaces**: Report No. 2-463. (Unpublished study received Sep

		27, 1974 under 5F1556; prepared by American Cyanamid Co., Princeton, N.J.; CDL:094673-R)
106777	**Summary 2037315**	American Cyanamid Co. (1974) Introduction to Environmental Chem- istry Studies with Prowl (AC 92,553). (Compilation; unpublished study received on unknown date under 5G1567; CDL:094279-A; 094280; 094281; 094282)
106782	**2037310**	Zulalian, J.; Godney, R.; Fasinski, R. (1973) CL 92,553--Metabo- lism V: Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) in Soil: PD-M 10:837-911. (Unpublished study received on un- known date under 4G1451; submitted by American Cyanamid Co., Princeton, NJ; CDL:094672-B)
153765	**2037457**	Mangels, G. (1985) Prowl Herbicide, Pendimethalin (AC 92,553): Adsorption/Desorption Studies: Project No. 0166: Report No. PD-M Volume 22-37. Unpublished study prepared by American Cyanamid Co. 76 p.
43041901		Mangels, G. (1993) Pendimethalin (AC 92,553): Adsorption/Desorption on Japanese Soils: Lab Project Number: PD/M/28/11: PD/M: E/90/3. Unpublished study prepared by American Cyanamid Co. 37 p.

163-2 Volatility - lab

MRID		Citation Reference
153766	**2037458**	Sanders, P. (1985) Prowl Herbicide, Pendimethalin (AC 92,553): Volatilization from Soil: Project No. 0166: Report No. PD-M Volume 22-38. Unpublished study prepared by American Cyanamid Co. 28 p.

164-1 Terrestrial field dissipation

MRID		Citation Reference
24857		Kennedy, J.M.; Talbert, R.E.; Fischer, B. (1974) ?Dinitroaniline Herbicides: Their Persistence on the Soil Surface, Residual Ac- tivity, and Relative Crop Tolerance|. (Unpublished study re- ceived 1975 under 2G1285; prepared by Univ. of Arkansas, Agri- cultural Experiment Station, submitted by Union Carbide Agricul- tural Products Co., Ambler, Pa.; CDL:095154-E)
26872		Moyer, M.; Potts, C.; Devine, J.M.; et al. (1975) Prowl^(R)I(CL 92,553): Determination of CL 92,553 ?N-(1-Ethylpropyl)-3,4-di- methyl-2,6-dinitrobenzenamine| and Sencor ?4-Amino-6-t-butyl-3- (methylthio)-1,2,4-triazin-5-one| in Soil: Report No. C-859. (Unpublished study received Nov 20, 1975 under 6F1704; submitted by American Cyanamid Co., Princeton, N.J.; CDL:094647-H)
26873		Potts, C.R.; Laporta, M.M.; Devine, J.; et al. (1975) Prowl^(R)I (CL 92,553): Determination of CL 92,553 ?N-(1-Ethylpropyl)-3,4- dimethyl-2,6-dinitrobenzenamine| and Sencor ?4-Amino-6-t-butyl- 3-(methylthio)-1,2,4-triazin-5(4H)-one| in Soil: Report No. C- 801. (Unpublished study received Nov 20, 1975 under 6F1704; submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094647-I)
46281	**2037413 Summary 2037315**	Barringer, D.F., Jr.; Zulalian, J.; Fisner, S.K. (1974) CL 92,553: Metabolism XI. The Behavior of CL 92,553 (Prowl Herbicide) in Soil, Part II. A 16-Month Field-Exposure Study: Project No. 2- 463. (Unpublished study received Sep 27, 1974

		under 5F1556; submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094475-H)
46294		Wyckoff, J.C.; Nzewi, G.I.; Roberts, W.W.; et al. (1974) ?Residue Study of Prowl, Atrazine, Bladex and Banvel in Soil|: Report No. C-518. (Reports by various sources; unpublished study in- cluding report no. C-517, received Sep 27, 1974 under 5F1556; submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-N)
46295	**2037420 Summary 2037315**	Nzewi, G.I.; Tondreau, R.E.; Jakowlew, S.; et al. (1974) ?Residue Study of Prowl in Soil|: Report No. C-473. (Reports by various sources; unpublished study including report nos. C-476, C-477, C-475..., received Sep 27, 1974 under 5F1556; submitted by Amer- ican Cyanamid Co., Princeton, N.J.; CDL:094673-C)
106782	**Summary 2037315 2037413**	Zulalian, J.; Godney, R.; Fasinski, R. (1973) CL 92,553--Metabo- lism V: Fate of Carbon-14 Labeled CL 92,553 (Prowl Herbicide) in Soil: PD-M 10:837-911. (Unpublished study received on un- known date under 4G1451; submitted by American Cyanamid Co., Princeton, NJ; CDL:094672-B)
106798	**Summary 2037315**	American Cyanamid Co. (1978) Amounts of Residues of Prowl, Its Metabolite (CL 202,347), Metribuzin (Sencor or Lexone) and Eptam in Soil. (Compilation; unpublished study received Oct 5, 1978 under 241-243; CDL:097435-A)
106805		Devine, J.; Kust, C.; Moyer, M.; et al. (1975) Prowl (CL 92,553): Determination of CL 92,553 ... and Sencor ... in Soil. Indi- ana.: Report No. C-859. (Unpublished study received Nov 14, 1975 under 6F1704; submitted by American Cyanamid Co., Prince- ton, NJ; CDL:097956-E)
106806	**2037454**	Devine, J.; Kust, C.; Potts, C.; et al. (1975) Prowl (CL 92,553): Determination of CL 92,553 ... and Sencor ... in Soil. Kan- sas. 1974: Report No. C-801. (Unpublished study received Nov 14, 1975 under 6F1704; submitted by American Cyanamid Co., Princeton, NJ; CDL:097956-F)
129090		American Cyanamid Co. (1979) ?Residue of Prowl Herbicide in Soil|. (Compilation; unpublished study received May 17, 1979 under 241- 243; CDL:238510-D)
5001077	**Summary 2037315**	Parochetti, J.V.; Dec, G.W., Jr.; Burt, G.W. (1976) Volatility of eleven dinitroaniline herbicides. Weed Science 24(6):529-532.
41725204	**2037464**	Steller, W.; Smyth, M. (1990) Pendimethalin (AC 92,553): Residues of AC 92,553 in Soil (Postemergence, Sandy Loam) Kerman, Cali- fornia--1988: Lab Project Number: C-3280. Unpublished study prepared by American Cyanamid Co. 90 p.
41725205		Sreller, W.; Smyth, M. (1990) Pendimethalin (AC 92,553): Residues of AC92, 553 in Soil (Post-emergence, Sandy) Brawley, California 1988: Lab Project Number: C-3281. Unpublished study prepared by American Cyanamid Co. 65 p.
41725206		Smyth, M; Koch, D.; Smith, J. (1990) Pendimethalin (AC 92, 553): Freezer Stability in Soil: Lab Project Number: C-3467. Unpub- lished study prepared by American Cyanamid Co. and Analytical Biochemistry Labs, Inc. 281 p.
43154701		Mangels, G.; Ahmed, Z. (1994) Pendimethalin Registration Standard--Response to EFGWB Review. Unpublished study prepared by American Cyanamid Co. 88 p.
45136801	**2002727**	Kukel, C. (2000) CL 92553 (Pendimethalin): Rate of Dissipation of CL 92553 Residues in Air and Soil After Treatment with Prowl 3.3 EC Herbicide Applied Pre-Plant Incorporated (PPI) to Soybeans in Indiana, U.S: Lab Project Number: PR98IN01: A011.294: A011.310. Unpublished study prepared by American Cyanamid Company, Heartland Technologies, H.E.R.A.C., Inc. and Maxim

		Technologies. 207 p.
45136802	**2002728**	Kukel, C. (2000) CL 92553 (Pendimethalin): Rate of Dissipation of CL 92553 Residues in Air and Soil After Treatment with Prowl 3.3 EC Herbicide Applied Pre-Emergence (PE) to Cotton in Louisiana, U.S: Lab Project Number: PR98LA02: A011.295: A011.311. Unpublished study prepared by American Cyanamid Company, H.E.R.A.C., Inc. and Maxim Technologies. 214 p.
45364705	**2002730 or 2002732**	Horton, W. (2001) CL 92553 (Pendimethalin): Comparison of the Rate of Dissipation of CL 92553 Residues in Soil Following a Single Preemergent Application of Either Prowl 3.3 EC Herbicide or Prowl 3.8 CS Herbicide to Cotton in Mississippi: Lab Project Number: RES 00-040: PR98MS01: M 820.04. Unpublished study prepared by BASF Agro Research Corporation and Maxim Technologies, Inc. 199 p.
45364706	**2002729**	Horton, W. (2001) CL 92553 (Pendimethalin): Comparison of the Rate of Dissipation of CL 92553 Residues in Soil Following a Single Pre-Plant Incorporation of Either Prowl 3.3 EC Herbicide or Prowl 3.8 CS Herbicide to Soybeans in Indiana: Lab Project Number: RES 00-039: PR9907: PR9907IN01. Unpublished study prepared by BASF Agro Research Corporation. 198 p.

164-2 Aquatic field dissipation

MRID		**Citation Reference**
29031		Tondreau, R.E. (1973) CL 92,553: N-(1-Ethylpropyl)-2,6-dinitro-3,4- xylidine Residues in Soil: Report No. C-355. Includes method M-388 dated Oct 25, 1973. (Unpublished study received on un- known date under 4G1451; submitted by American Cyanamid Co., Princeton, N.J.; CDL:093869-Q)
29032	**2037407**	Bodnarchuk, D.; Moyer, M.; Tondreau, R.E.; et al. (1973) Prowl: Determination of CL 92,553...Residues in Soil (Waseca, Minneso- ta) Treated by Pre-emergence Spray: Report No. C-400. Includes method M-437 dated Oct 25, 1973. (Unpublished study received on unknown date under 4G1451; submitted by American Cyanamid Co., Princeton, N.J.; CDL:093869-R)
31976		Boughton, P.J.; Benson, G.L.; Moyer, M.; et al. (1975) Residue Sum- maries--Pay-Off Tobacco Sucker Control Agent. (Unpublished study received Mar 18, 1975 under 241-247; prepared in coopera- tion with U.S. Agricultural Research Service and others, submit- ted by American Cyanamid Co., Princeton, N.J.; CDL:050910-D)
67293	**Summary 2037315**	Marei, A.H.; Haugwitz, M.I.; Eisner, S.K. (1974) CL 92,553: Metabo- lism: XII. Residual Radioactivity in Rice Grain and Plants Grown in Soil Treated with Carbon-14 CL 92,553: PD-M 11:376-416. Fi- nal rept. (Unpublished study received Aug 25, 1980 under 241- 243; submitted by American Cyanamid Co., Princeton, N.J.; CDL: 099565-K)
41245601	**2037465**	Manual, A. (1980) Analysis for Residues of Prowl in Soil and in Water from Prowl Treated Rice Fields: Report No. CY 17. Unpub- lished study prepared by American Cyanamid Co. 114 p.

165-4 Bioaccumulation in fish

MRID	**Citation Reference**

158235 and 156726	**2037459**	Forbis, A.; Burgess, D.; Burnett, J. (1986) Uptake, Depuration and Bioconcentration of [Carbon-14]-AC 92,553 by Bluegill Sunfish (Lepomis macrochirus): PD-M Volume 23-17; ABC Final Report # 33408. Unpublished study prepared by Analytical Bio-Chemistry Laboratories, Inc. 276 p.

71124 McAllister, W.A.; Thompson, C.M.; Forbis, A.D.; et al. (1980) Resi- due Accumulation Study in Crayfish (~Procambarus simulans~) with ^14IC-CL 92,553 (Pendimethalin) under Static Conditions: Final Residue Accumulation Report # 25687. (Unpublished study received Jan 22, 1981 under 241-243; prepared by Analytical Bio Chemistry Laboratories, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:099889-C)

8.2. Submitted Ecotoxicity Studies

71-1 Avian Single Dose Oral Toxicity

MRID		Citation Reference
59739	2037321	Fink, R. (1976) Final Report: Acute Oral LD50--Mallard Duck: Project No. 130-110. (Unpublished study received 1976 under 241-243; prepared by Truslow Farms, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:228391-B)
49397804	DER not located	Stark, D. (2014) BAS 455 H (Pendimethalin) - Acute Toxicity in the Canary (Serinus canaria) After Single Oral Administration (LD50). Project Number: 15W0139/02W004, 438123, 2014/1132793. Unpublished study prepared by BASF Gewerbehygiene und Toxikologie. 43p.

71-2 Avian Dietary Toxicity

MRID		Citation Reference
26674 or 52577 or 72900	2037317	Fink, R. (1973) Final Report: Eight-Day Dietary LCI50^--Mallard Ducks: **Project No. 362-138**. (Unpublished study received on un- known date under 4G1451; prepared by Hazleton Laboratories, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:093868-X)
26675 or 52578 or 72899	DER not located	Fink, R. (1973) Final Report: Eight-Day Dietary LCI50^--Bobwhite Quail: **Project No. 362-137**. (Unpublished study received on un- known date under 4G1451; prepared by Hazleton Laboratories, sub- mitted by American Cyanamid Co., Princeton, N.J.; CDL:093868-Y)
29791	DER not located	Shaffer, C.B. (1974) ?Toxicology Studies of Prowl Herbicide|. (Un- published study received Dec 21, 1974 under 5G1580; submitted by American Cyanamid Co., Princeton, N.J.; CDL:094331-A)

52577	2007317	Fink, R. (1973) Final Report: Eight-Day Dietary LCI50^--Mallard Ducks: **Project No. 362-138**. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Environmental Sciences Corp., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094232-H)
52578	See 26675 above	Fink, R. (1973) Final Report: Eight-Day Dietary LC50--Bobwhite Quail: **Project No. 362-137**. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Environmental Sciences Corp., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094232-I)
72899	2087896	Fink, R. (1973) Final Report: Eight-Day Dietary LCI50^--Bobwhite Quail: Project No. 362-137. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Environmental Sciences Corp., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-H)
72900	2087896	Fink, R. (1973) Final Report: Eight-Day Dietary LCI50^--Mallard Ducks: Project No. 362-138. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Environmental Sciences Corp., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-I)

71-4 Avian Reproduction

MRID		Citation Reference
44907601	2037344	Beavers, J.; Foster, J.; Jaber, M. et al. (1996) Reproduction Study with AC 92553 Technical in Mallard (Anas platyrhynchos): Lab Project Number: 954-93-195: 130-171: TAN 95-004. Unpublished study prepared by Wildlife International, Ltd. 270 p. {OPPTS 850.2300}
44907602	2037345	Beavers, J.; Foster, J.; Jaber, M. et al. (1996) Reproduction Study with AC 92553 Technical in the Northern Bobwhite (Colinus virginianus): Lab Project Number: 954-93-197: 130-170: TAN 95-004. Unpublished study prepared by Wildlife International, Ltd. 274 p.

72-1 Acute Toxicity to Freshwater Fish

MRID		Citation Reference
106764 or 37778 or 46291	2037331 2037320	Sleight, B. (1973) Acute Toxicity of AC-92553 to Bluegill (Lepomis macrochirus), Rainbow Trout (Salmo gairdneri) and Channel Cat- Fish (Ictaluras punctatus). (Unpublished study received on unknown date under 5G1567; prepared by Bionomics, Inc., sub- mitted by American Cyanamid Co., Princeton, NJ; CDL:094287-E)
131773	2037330	LeBlanc, G.; Sousa, J. (1983) Acute Toxicity of AC 92,553 to Chan- nel Catfish ...: Report #BW-83-2-1361. (Unpublished study re- ceived Oct 28, 1983 under 241-243; prepared by EG & G Bionomics, submitted by American Cyanamid Co., Princeton, NJ; CDL:251601-

		C)
37778	See 106764 above	Sleight, B.H., III (1972) Bioassay Report: Acute Toxicity of AC-92553 to Bluegill (?~Lepomis macrochirus~?), Rainbow Trout (?~Salmo gairdneri~?) and Channel Catfish (?~Ictaluras puncta~?-?~tus~?). (Unpublished study received on unknown date under 4G1451; prepared by Bionomics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:093868-W)
46291	2037320	Sleight, B.H., III (1972) Acute Toxicity of AC-92553 to Bluegill (~Lepomis macrochirus~), Rainbow Trout (~Salmo gairdneri~) and Channel Catfish (~Ictaluras punctatus~). (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Bionomics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-E)
46292 or 37927?	2037318	Bentley, R.E. (1974) Acute Toxicity of Prowl^(TM)I 3E, Prowl^(TM)I 4E, and Avenge 2A-S to Bluegill (~Lepomis macrochirus~) and Rainbow Trout (~Salmo gairdneri~). (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Bionomics EG&G, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-F)
37927	2037318	Bentley, R.E. (1974) Acute Toxicity of Prowl^(TM)I 3E, Prowl^(TMI) 4E, and Avenge 2A-S to Bluegill (?~Lepomis macrochirus?~) and Rainbow Trout (?~Salmo gairdneri?~). (Unpublished study received Nov 14, 1975 under 6F1703; prepared by Bionomic, EG&G, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094732-H)

72-2 Acute Toxicity to Freshwater Invertebrates

MRID		Citation Reference
59738	2037322	LeBlanc, G.A. (1976) Acute Toxicity of Prowl to~Daphnia magna~. (Unpublished study received 1976 under 241-243; prepared by Bio-nomics, EG&G, submitted by American Cyanamid Co., Princeton, N.J.; CDL:228391-A)
71123	2037326	Thompson, C.M.; Griffen, J.; McAllister, W.A. (1980) Acute Toxicity of AC 92,553 to the Freshwater Crayfish (Procambarus simulans): Static Acute Bioassay Final Report # 25725. (Unpublished study received Jan 22, 1981 under 241-243; prepared by Analytical Bio Chemistry Laboratories, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:099889-B)
153772	2037525	Forbis, A.; Georgie, L.; Burgess, D. (1985) Acute Toxicity of AC 92,553 4E to Daphnia magna: Static Acute Toxicity Report #33409. Unpublished study prepared by Analytical Bio-Chemistry Laboratories, Inc. 39 p.

72-3 Acute Toxicity to Estuarine/Marine Organisms

MRID		Citation Reference
131772	2037333	Ward, G. (1983) Acute Toxicity of AC 92,553 Technical and Formulated to Embryos-larvae of Eastern Oysters ...: Report No. BP-83- 6-65; Project No. R95. (Unpublished study received Oct 28, 1983 under 241-1243; prepared by EG & G Bionomics, submitted by American Cyanamid Co., Princeton, NJ; CDL:251601-A)
131774	2037334	Ward, G.; Shuba, P. (1983) Acute Toxicity of AC 92,553 Technical and Formulation to Sheepshead Minnows ...: Report No. BP-83-3- 39; Project No. R95. (Unpublished study received Oct 28, 1983 under 241-243; prepared by EG & G Bionomics, submitted by American Cyanamid Co., Princeton, NJ; CDL:251601-E)
131775	2037335	Ward, G.; Shuba, P. (1983) Acute Toxicity of AC 92,553 Technical and Formulation to Pink Shrimp ...: Report No. BP-83-1-5; Pro- ject No. R95. (Unpublished study received Oct 28, 1983 under 241-243; prepared by EG & G Bionomics, submitted by American Cy- anamid Co., Princeton, NJ; CDL:251601-G)

72-4 Fish Early Life Stage/Aquatic Invertebrate Life Cycle Study

MRID		Citation Reference
29791	2087896	Shaffer, C.B. (1974) ?Toxicology Studies of Prowl Herbicide|. (Un- published study received Dec 21, 1974 under 5G1580; submitted by American Cyanamid Co., Princeton, N.J.; CDL:094331-A)
37940	2037319	EG&G, Bionomics (1975?) Chronic Toxicity of CL-92,553 to the Fat- head Minnow (Pimephales promelas). (Unpublished study received Sep 8, 1977 under 241-243; submitted by American Cyanamid Co., Princeton, N.J.; CDL:096342-A)
37778	2087896	Sleight, B.H., III (1972) Bioassay Report: Acute Toxicity of AC- 92553 to Bluegill (Lepomis macrochirus), Rainbow Trout (Salmo gairdneri) and Channel Catfish (Ictaluras punctatus). (Unpublished study received on unknown date under 4G1451; prepared by Bionomics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL:093868-W)
37927	2087896	Bentley, R.E. (1974) Acute Toxicity of Prowl^(TM)I 3E, Prowl^(TMI) 4E, and Avenge 2A-S to Bluegill (?~Lepomis macrochirus?~) and Rainbow Trout (?~Salmo gairdneri?~). (Unpublished study re- ceived Nov 14, 1975 under 6F1703; prepared by Bionomics, EG&G, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094732-H)
37940	2087896	EG&G, Bionomics (1975?) Chronic Toxicity of CL-92,553 to the Fathead Minnow (Pimephales promelas). (Unpublished study received Sep 8, 1977 under 241-243; submitted by American Cyanamid Co., Princeton, N.J.; CDL:096342-A)
41993	DER not	Sleight, B.H., III (1976) Letter sent to John Wyckoff dated Feb 19, 1976

	located	?Exposure of fathead minnows to CL-92,553|. (Unpublished study received Feb 27, 1976 under 5F1556; prepared by EG&G, Bionomics, submitted by American Cyanamid Co., Princeton, N.J.; CDL:095521-A)
46291	2087896	Sleight, B.H., III (1972) Acute Toxicity of AC-92553 to Bluegill (~Lepomis macrochirus~), Rainbow Trout (~Salmo gairdneri~) and Channel Catfish (~Ictaluras punctatus~). (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Bionomics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-E)
46292	2087896	Bentley, R.E. (1974) Acute Toxicity of Prowl^(TM)I 3E, Prowl^(TM)I 4E, and Avenge 2A-S to Bluegill (~Lepomis macrochirus~) and Rainbow Trout (~Salmo gairdneri~). (Unpublished study re- ceived Sep 27, 1974 under 5F1556; prepared by Bionomics EG&G, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 094674-F)
100504	2037323 2037329	Graney, R.L. (1981) The Chronic (21 Day) Toxicity of AC 92,553 to ?~Daphnia magna~Straus: Project No. 5179. (Unpublished study received Apr 20, 1982 under 241-243; prepared by Biospherics, Inc., submitted by American Cyanamid Co., Princeton, N.J.; CDL: 247299-A)
158305	Letter	Sauter, S. (1976) Letter sent to J. Wyckoff dated Aug 3, 1976: Chronic exposure of fathead minnows to Prowl. 6 p.
106819	Letter	Sauter, S. (1978**) Letter sent to R. Barron dated Feb 20, 1978 ?**Chronic toxicity test with fathead minnows and CL-92,553|. (Unpublished study received Mar 22, 1978 under 241-243; prepared by EG & G Bionomics, submitted by American Cyanamid Co., Prince- ton, NJ; CDL:233264-A)

72-5 Life cycle fish

MRID		Citation Reference
37940	2037319	EG&G, Bionomics (1975?) Chronic Toxicity of CL-92,553 to the Fat- head Minnow (Pimephales promelas). (Unpublished study received Sep 8, 1977 under 241-243; submitted by American Cyanamid Co., Princeton, N.J.; CDL:096342-A)
58831	2037324	Sleight, B.H., III (1976) Letter sent to John Wyckoff dated Apr 20, 1976 (Progress report on chronic exposure of fathead minnows to CL- 92,553). (Unpublished study received Jun 1, 1976 under 241- 243; prepared by EG&G, Bionomics, submitted by American Cyanamid Co., Princeton, N.J.; CDL:224592-A)
58833	2037325	Sleight, B.H., III (1976) Letter sent to John Wyckoff dated May 21, 1976 ?Raw data for water samples from fathead minnow chronic ex- posure study with Prowl|. (Unpublished study received Jun 1, 1976 under 241-243; prepared by EG&G, Bionomics, submitted by American Cyanamid Co., Princeton, N.J.; CDL:224592-C)

72-6 Aquatic org. accumulation

MRID	Citation Reference

156726	2037526	Forbis, A.; Burgess, D.; Burnett, J. (1986) Uptake, Depuration and Bioconcentration of [Carbon-14]-AC 92,553 by Bluegill Sunfish (Lepomis macrochirus): Final Report #33408. Unpublished study prepared by Analytical Bio-Chemistry Laboratories, Inc. 277 p.

123-1 Seed germination/seedling emergence and vegetative vigor

MRID		Citation Reference
42372201	2037337	Chetram, R.; Gagne, J. (1992) A Tier 2 Plant Phytotoxicity Study for Seedling Emergence Using AC 92,553: Pendimethalin: Lab Project Number: BL91-453. Unpublished study prepared by American Cyanamid Comp. and Pan-Agricultural Laboratories, Inc. 243 p.
42372202	2037338	White, T.; Gagne, J. (1992) A Tier 2 Plant Phytoxicity Study for Seed Germination Using AC 92,553: Pendimethalin: Lab Project Number: BL91-471. Unpublished study prepared by American Cyanamid Comp. and Pan-Agricultural Laboratories, Inc. 131 p.
42372203	2037339	Canez, V; Gagne, J. (1992) A Tier 2 Plant Phytoxicity Study for Vegetative Vigor Using AC 92,553: Pendimethalin: Lab Project Number: BL91-454. Unpublished study prepared by American Cyanamid Comp. and Pan-Agricultural Laboratories, Inc. 212 p.

123-2 Aquatic plant growth

MRID		Citation Reference
42137101	No DER See 2037379 or 2037381	Hughes, J.; Alexander, M.; Wisk, J. (1991) Effect of AC 92,553 on Growth of Duckweed, Lemna gibba: Lab Project Number: B400-31-1. Unpublished study prepared by Malcolm Pirnie, Inc. 60 p.
42372204	2037340	Hughes, J.; Alexander, M.; Wisk, J. (1992) Effect of AC 92,553 on Growth of the Green Alga, Selenastrum Capricornutum: Pendimethalin: Lab Project Number: B400-32-1. Unpublished study prepared by American Cyanamid Comp. and Malcolm Pirnie, Inc. 58 p.
42372205	2037341	Hughes, J.; Alexander, M.; Wisk, J. (1992) Effect of AC 92,553 on Growth of the Marine Diatom, Skeletonema Costatum: Pendimethalin: Lab Project Number: B400-32-4. Unpublished study prepared by American Cyanamid Comp. and Malcolm Pirnie, Inc. 53 p.
42372206	2037342	Hughes, J.; Alexander, M.; Wisk, J. (1992) Effect of AC 92,553 on Growth of the Freshwater Diatom, Navicula Pelliculosa: Pendimethalin: Lab Project Number: B400-32-3. Unpublished study prepared by American Cyanamid Comp. and Malcolm Pirnie, Inc. 53 p.

42372207	2037343	Hughes, J.; Alexander, M.; Wisk, J. (1992) Effect of AC 92,553 on Growth of the Blue-Green Alga, Anabaena Flos-Aquae: Pendimethalin: Lab Project Number: B400-32-2. Unpublished study prepared by American Cyanamid Comp. and Malcolm Pirnie, Inc. 60 p.
47954502	Open lit	Ma, J.; Liang, W.; Xu, L.; et al. (2000) Acute Toxicity of 33 Herbicides to the Green Alga Chlorella pyrenoidosa. Bulletin of Environmental Contamination and Toxicology 66:536-541.
47954503	Open lit	Ma, J. (2001) Differential Sensitivity to 30 Herbicides Among Populations of Two Green Algae Scenedesmus obliquus and Chlorella pyrenoidosa. Bulletin of Environmental Contamination and Toxicology 68:275-281.
47954504	Open lit	Ma, J.; Xu, L.; Wang, S.; et al. (2001) Toxicity of 40 Herbicides to the Green Alga Chlorella vulgaris. Exotoxicology and Environmental Safety 51:128-132.
47954505	Open lit	Ma, J.; Lin, F.; Wang, S.; et al. (2004) Acute Toxicity Assessment of 20 Herbicides to the Green Alga Scenedesmus quadricauda (Turp.) Breb. Bulletin of Environmental Contamination and Toxicology 72: 1164-1171.

141-1 Honeybee Toxicity

51271 or 108773	2037332	Atkins, E.L. (1974) Letter sent to A.J. Tafuro dated May 20, 1974 ?Toxicity of Prowl to honeybees|. (Unpublished study received Sep 27, 1974 under 5F1556; prepared by Univ. of California-- Riverside, Citrus Research Center and Agricultural Experiment Station, Dept. of Entomology, submitted by American Cyanamid Co., Princeton, N.J.; CDL:094674-M)
99890	2037327 2037328	Atkins et al at UCR Honeybee acute
49207707	Contract draft Cambridge	Strnad, S.; Mulligan, E. (1999) Acute Toxicity of Pendimethalin (AC 92553) Technical to the Honey Bee, Apis mellifera. Project Number: ETX/99/227, PN/541/011. Unpublished study prepared by American Cyanamid Co. 40p.

850.4100 Terrestrial plant toxicity, Tier 1 (seeding emergence)

MRID		Citation Reference
49207708	Contract draft Cambridge	Stroemel, C.; Friedemann, A.; Teressiak, H. (2013) Effect of BAS 455 48 H on Seedling Emergence and Seedling Growth of Ten Species of Terrestrial Plants under Greenhouse Conditions. Project Number: 428908, 2726599, AC/BASF/12/22. Unpublished study prepared by Agro-Check. 130p.

850.4150 Terrestrial plant toxicity, Tier 1 (vegetative vigor)

MRID		Citation Reference
49207709	Contract draft	Stroemel, C.; Friedemann,A.; Teresiak, H. (2013) Effect of BAS 455 48 H on Vegetative Vigour of Ten Species of Terrestrial Plants under Greenhouse Conditions. Project Number: 428909, 2726602, AC/BASF/12/23. Unpublished study prepared by Agro-Check. 101p.

850.1790 Chironomid Sediment Toxicity Test

MRID		Citation Reference
47891601	Contract draft Cambridge	Backfisch, K. (2009) Chronic Toxicity of Pendimethalin (BAS 455 H) to the Non-Biting Midge Chironomus riparius: A Spiked Sediment Study. Project Number: 326800, 2008/1010543. Unpublished study prepared by BASF SE. 35 p.

850.7100 Data reporting for environmental chemistry methods

MRID		Citation Reference
49397803		Shen, X.; Michener, P. (2014) Independent Laboratory Validation of the Method Determining the Residues of Pendimethalin in Soil: Amended Final Report. Project Number: 053/0963, 438119, PASC/REP/0466. Unpublished study prepared by Primera Analytical Solutions Corporation. 47p.

Appendix A

Selected PWC Output Files

Summary of Water Modeling of Pendimethalin and the USEPA Standard Pond

LA Sugarcane (Aerial Application)

Table 1. Estimated Environmental Concentrations (ppb) for Pendimethalin .

Peak (1-in-10 yr)	43.7
4-day Avg (1-in-10 yr)	27.3
21-day Avg (1-in-10 yr)	11.9
60-day Avg (1-in-10 yr)	8.44
365-day Avg (1-in-10 yr)	4.76
Entire Simulation Mean	3.96

Table 2. Summary of Model Inputs for Pendimethalin.

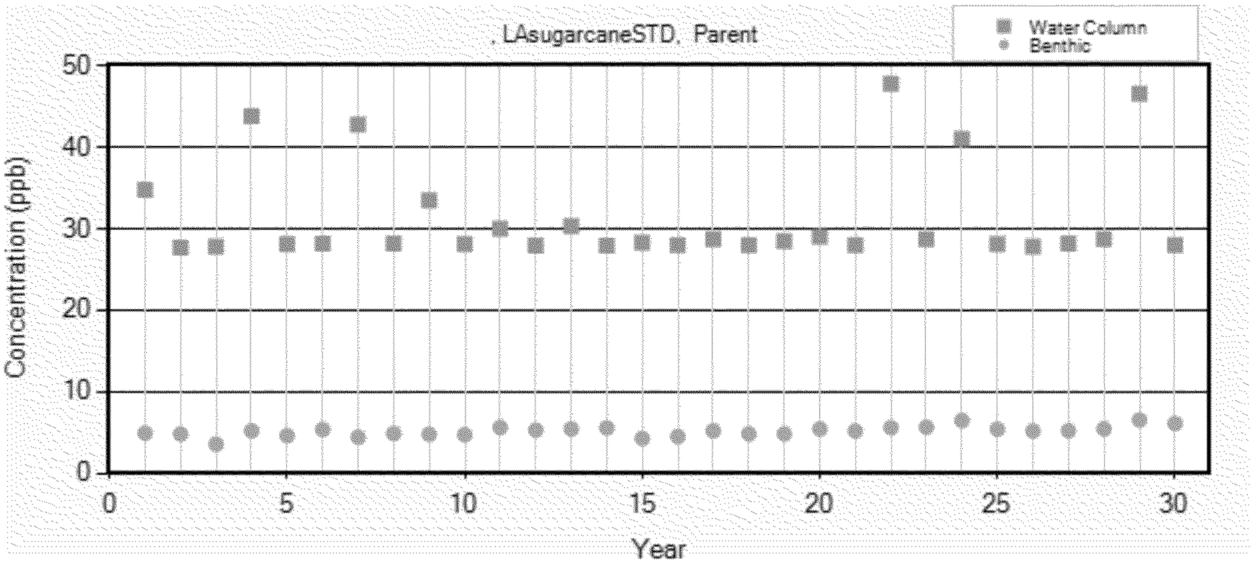
Scenario	LAsugarcaneSTD
Cropped Area Fraction	1
Koc (ml/g)	17040
Water Half-Life (days) @ 24.1 °C	72.3
Benthic Half-Life (days) @ 25 °C	64
Photolysis Half-Life (days) @ 40 °Lat	21
Hydrolysis Half-Life (days)	0
Soil Half-Life (days) @ 22 °C	690
Foliar Half-Life (days)	0
Molecular Weight	281.31
Vapor Pressure (torr)	9.4 E-6
Solubility (mg/l)	0.3
Henry's Constant	0.0

Table 3. Application Schedule for Pendimethalin.

Date (Mon/Day)	Type	Amount (kg/ha)	Eff.	Drift

9/23	Above Crop (Foliar)	4.48	0.95	0.125
10/23	Above Crop (Foliar)	2.24	0.95	0.125

Figure 1. Yearly Peak Concentrations



LA Sugarcane (Ground Application)

Table 1. Estimated Environmental Concentrations (ppb) for Pendimethalin.

Peak (1-in-10 yr)	41.4
4-day Avg (1-in-10 yr)	26.3
21-day Avg (1-in-10 yr)	10.9
60-day Avg (1-in-10 yr)	7.84
365-day Avg (1-in-10 yr)	4.15
Entire Simulation Mean	3.44

Table 2. Summary of Model Inputs for Pendimethalin.

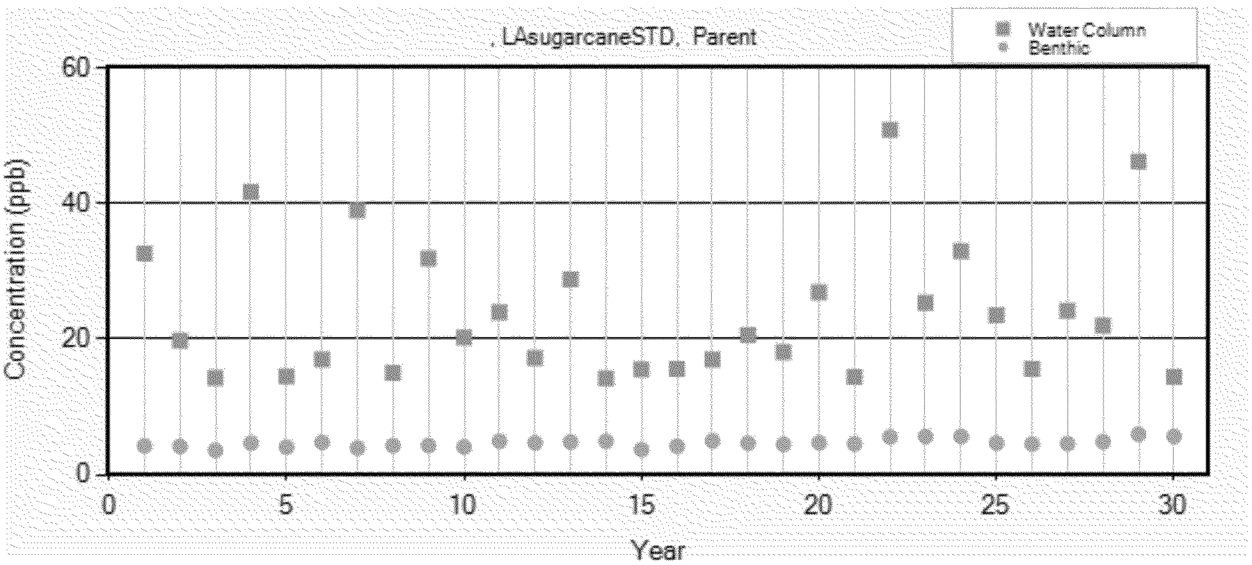
Scenario	LAsugarcaneSTD
Cropped Area Fraction	1
Koc (ml/g)	17040

Water Half-Life (days) @ 24.1 °C	72.3
Benthic Half-Life (days) @ 25 °C	64
Photolysis Half-Life (days) @ 40 °Lat	21
Hydrolysis Half-Life (days)	0
Soil Half-Life (days) @ 22 °C	690
Foliar Half-Life (days)	0
Molecular Weight	281.31
Vapor Pressure (torr)	9.4 E-6
Solubility (mg/l)	0.3
Henry's Constant	0.0

Table 3. Application Schedule for Pendimethalin.

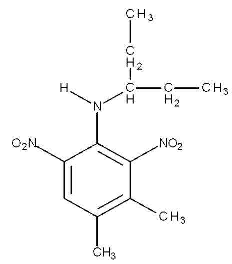
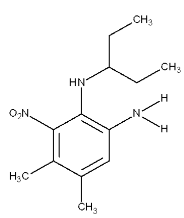
Date (Mon/Day)	Type	Amount (kg/ha)	Eff.	Drift
9/23	Ground	4.48	0.99	0.062
10/23	Ground	2.24	0.99	0.062

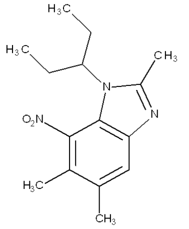
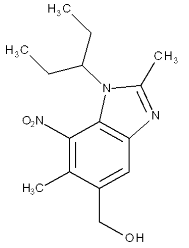
Figure 1. Yearly Peak Concentrations

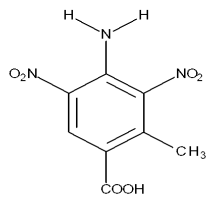
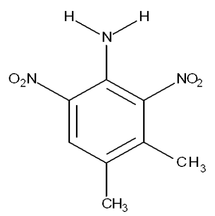
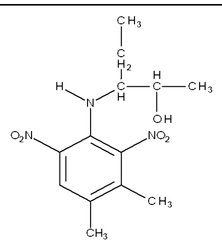


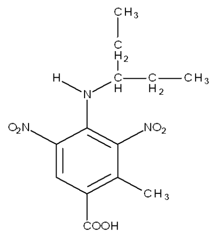
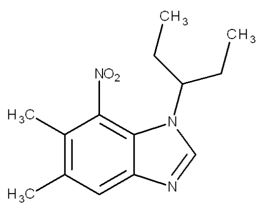
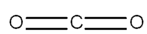
Appendix B

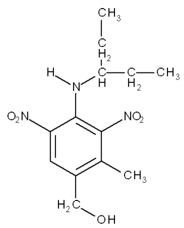
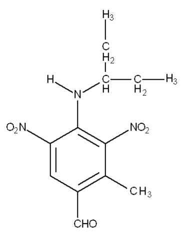
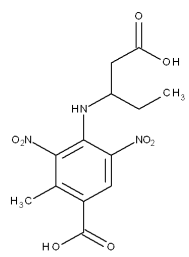
Table B-1$_A$

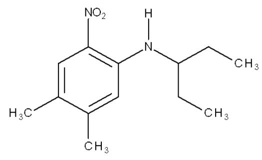
Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)		Final %AR (study length)
PARENT							
Pendimethalin (AC 92553, CL 92553, BAS 455 H)	**IUPAC:** N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine **CAS:** N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine **CAS No.:** 40487-42-1 **Formula:** $C_{13}H_{19}N_3O_4$ **MW:** 281.31 g/mol **SMILES:** CCC(CC)Nc1c(cc(C)c(C)c1N(=O)=O)N(=O)=O		835.4100 Aerobic soil metabolism	49207701	Sandy loam	**100.3%** (0 d)	**61.1%** (120 d)
					Silt loam	**96.3%** (0 d)	**75.5%** (120 d)
					Clay loam	**98.1%** (0 d)	**77.2%** (120 d)
				49207702	Sandy loam	**101.1%** (0 d)	**41.9%** (120 d)
				49207703	LUFA 5M Loamy sand	**106.4%** (0 d)	**38.3%** (119 d)
					Speyerer Wald 2, Loamy sand	**100.9%** (0-1 d)	**67.2%** (119 d)
					LUFA 2.3 Sandy loam	**101.1%** (0 d)	**28.0%** (119 d)
			835.4200 Anaerobic soil metabolism	49207705	Loamy sand	**98.3%** (0 d)	3.4% (150 d)
MAJOR (>10%) TRANSFORMATION PRODUCTS							
P48	**IUPAC:** 4,5-Dimethyl-3-nitro-N2-(pentan-3-yl)benzene-1,2-diamine **Formula:** $C_{13}H_{21}N_3O_2$ **MW:** 251.3 g/mol **SMILES:** CCC(CC)Nc1c(cc(c(c1[N+](=O)[O-])C)C)N		835.4200 Anaerobic soil metabolism	49207705	Loamy sand	**15.0%** (44 d)	ND (150 d)

P26	**IUPAC:** 1-(1-Ethylpropyl)-2,5,6-trimethyl-7-nitro-benzimidazole **Formula:** $C_{15}H_{21}N_3O_2$ **MW:** 275.16 g/mol **SMILES:** CCC(CC)n1c(nc2c1c(c(c(c2)C)C)[N+](=O)[O-])C		835.4200 Anaerobic soil metabolism	49207705	Loamy sand	**13.9%** (62 d)	ND (150 d)
P23	**IUPAC:** [1-(1-Ethylpropyl)-2,6-dimethyl-7-nitro-benzimidazol-5-yl]methanol **Formula:** $C_{15}H_{21}N_3O_3$ **MW:** 291.15 g/mol **SMILES:** CCC(CC)n1c(nc2c1c(c(c(c2)CO)C)[N+](=O)[O-])C		835.4200 Anaerobic soil metabolism	49207705	Loamy sand	**11.8%** (62 d)	ND (150 d)
Unextractable residues	NA	NA	835.4100 Aerobic soil metabolism	49207701	Sandy loam	**10.5%** (120 d)	**10.5%** (120 d)
				49207702	Sandy loam	**36.2%** (91 d)	**34.9%** (120 d)
			835.4200 Anaerobic soil metabolism	49207705	Loamy sand	**71.0%** (90 d)	**64.2%** (150 d)
MINOR (<10%) TRANSFORMATION PRODUCTS							

CL 202078	**IUPAC:** 4-Amino-3,5-dinitro-o-toluic acid **Formula:** $C_8H_7N_3O_6$ **MW:** 241.2 g/mol **SMILES:** Cc1c(cc(c(c1[N+](=O)[O-])N)[N+](=O)[O-])C(=O)O		835.4100 Aerobic soil metabolism	49207701	Sandy loam		0.3% (120 d)	0.3% (120 d)
CL 84846	**IUPAC:** 2,6-Dinitro-3,4-xylidine **Formula:** $C_8H_9N_3O_4$ **MW:** 211.2 g/mol **SMILES:** Cc1cc(c(c(c1C)[N+](=O)[O-])N)[N+](=O)[O-]		835.4100 Aerobic soil metabolism	49207701	Sandy loam		0.4% (84 d)	NR
					Silt loam		0.2% (120 d)	0.2% (120 d)
					Clay loam		0.7% (120 d)	0.7% (120 d)
			835.4200 Anaerobic soil metabolism	49207705	Loamy sand		ND	ND
CL 113066	**IUPAC:** 3-(2,6-Dinitro-3,4-xylidino)-2-pentanol **Formula:** $C_{13}H_{19}N_3O_5$ **MW:** 297.3 g/mol **SMILES:** CCC(C(C)O)Nc1c(cc(c(c1[N+](=O)[O-])C)C)[N+](=O)[O-]		835.4100 Aerobic soil metabolism	49207701	Sandy loam	Isomer # 1	3.5% (120 d)	3.5% (120 d)
						Isomer # 2	0.6% (120 d)	0.6% (120 d)
CL 99900 (M455H001, P44)	**IUPAC:** 4-((1-Ethylpropyl)amino)-2-methyl-3-5-dinitrobenzoic acid		835.4100 Aerobic soil metabolism	49207701	Sandy loam		1.6% (120 d)	1.6% (120 d)
					Silt loam		0.5% (120 d)	0.5% (120 d)
					Clay loam		0.5% (56 d)	NR
				4920770			6.9% (120 d)	6.9% (120 d)

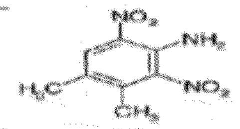
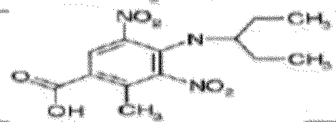
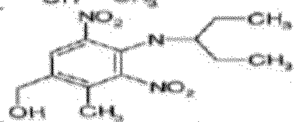
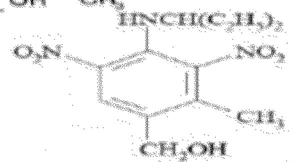
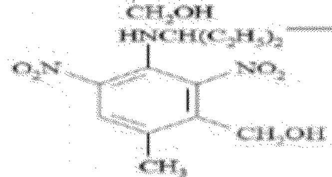
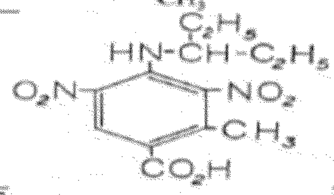
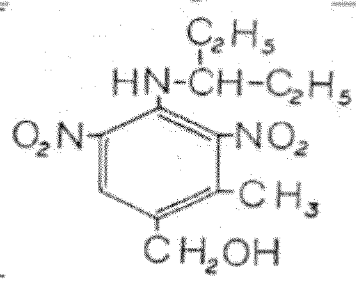
	CAS: 4-[(1-Ethyl-propyl)amino]-3,5-dinitro-o-toluic acid **Formula:** $C_{13}H_{17}N_3O_6$ **MW:** 311.3 g/mol **SMILES:** CCC(CC)Nc1c(cc(c(c1[N+](=O)[O-])C)C(=O)O)[N+](=O)[O-]			2			
				49207703	LUFA 5M Loamy sand	5.5% (119 d)	5.5% (119 d)
					Speyerer Wald 2, Loamy sand	1.9% (58-119 d)	1.9% (119 d)
					LUFA 2.3 Sandy loam	2.9% (58 d)	2.5% (119 d)
			835.4200 Anaerobic soil metabolism	49207705	Loamy sand	0.7% (37 d)	ND (150 d)
P36	**IUPAC:** 1-(1-Ethylpropyl)-5,6-dimethyl-7-nitro-1H-benzimidazole **Formula:** $C_{14}H_{19}N_3O_2$ **MW:** 261.3 g/mol **SMILES:** CCC(CC)n1cnc2c1c(c(c(c2)C)C)[N+](=O)[O-]		835.4200 Anaerobic soil metabolism	49207705	Loamy sand	6.9% (90 d)	5.0% (150 d)
Carbon dioxide	**IUPAC:** Carbon dioxide **Formula:** CO_2 **MW:** 44 g/mol **SMILES:** C(=O)=O		835.4100 Aerobic soil metabolism	49207701	Sandy loam	2.3% (120 d)	2.3% (120 d)
					Silt loam	2.4% (120 d)	2.4% (120 d)
					Clay loam	1.7% (120 d)	1.7% (120 d)
				49207702	Sandy loam	6.9% (120 d)	6.9% (120 d)
			835.4200 Anaerobic soil metabolism	49207705	Loamy sand	0.498% (90 d)	0.437% (150 d)
REFERENCE COMPOUNDS NOT IDENTIFIED							
CL 202347	**IUPAC:** [4-(1-Ethylpropylamino)-2-methyl-3,5-dinitro-phenyl]methanol		835.4100 Aerobic soil	4920770	NA	NA	

	Formula: $C_{13}H_{19}N_3O_5$ **MW:** 297.3 g/mol **SMILES:** CCC(CC)Nc1c(cc(c(c1[N+](=O)[O-])C)CO)[N+](=O)[O-]		metabolism 835.4200 Anaerobic soil metabolism	1 49207705		
CL 233220	**IUPAC:** 4-(1-Ethylpropylamino)-2-methyl-3,5-dinitro-benzaldehyde **Formula:** $C_{13}H_{17}N_3O_5$ **MW:** 295.3 g/mol **SMILES:** CCC(CC)Nc1c(cc(c(c1[N+](=O)[O-])C)C=O)[N+](=O)[O-]		835.4100 Aerobic soil metabolism	49207701	NA	NA
CL 113071	**IUPAC:** 4-[(1-(Carboxymethyl)propyl)amino]-2-methyl-3,5-dinitro-benzoic acid **Formula:** $C_{13}H_{15}N_3O_8$ **MW:** 341.3 g/mol **SMILES:** CCC(CC(=O)O)Nc1c(cc(c(c1[N+](=O)[O-])C)C(=O)O)[N+](=O)[O-]		835.4200 Anaerobic soil metabolism	49207705	NA	NA

CL 94049	**IUPAC:** N-(1-Ethylpropyl)-6-nitro-3,4-xylidine **Formula**: $C_{13}H_{20}N_2O_2$ MW: 236.3 g/mol **SMILES:** CCC(CC)Nc1cc(c(cc1[N+](=O)[O-])C)C		835.4200 Anaerobic soil metabolism	49207705	NA	NA

[A] AR means "applied radioactivity". MW means "molecular weight". ND means "not detected". NR means "not reported". NA means "not applicable".

Table B-2

Number	Structure	Name
1		2,6-Dinitro-3,4-dimethylaniline
2 acid		N-(1 -Ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline
3 alcohol		(4-[(1 -Ethylpropyl)amino]-2-methyl-3,5-dinitrophenyl)methanol
4 alcohol		3,5-Dinitrobenzyl alcohol metabolite
5 alcohol		2,4-Dinitrobenzyl alcohol metabolite
6 acid		4-[(l-ethylpropy1)aminol-3,5-dinitro-o-touc acid
7 alcohol		4-[(1-ethyl-propyl)amino]-2-methyl-3,5-dinitro benzyl alcohol